UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

DTIC FILE COPY

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS --
AD-A211 751	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Research Note 88-116
6a. NAME OF PERFORMING ORGANIZATION Mellonics Systems Development Division Litton Systems, Inc. 6b. OFFICE SYMBOL (If applicable) --	7a. NAME OF MONITORING ORGANIZATION U.S. Army Research Institute Field Unit at Fort Benning, Georgia
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 3407 Sunnyvale, CA 94088-3407	7b. ADDRESS (City, State, and ZIP Code) P.O. Box 2086 Fort Benning, GA 31905
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences 8b. OFFICE SYMBOL (If applicable) PERI-I	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA903-83-C-0545
8c. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 63744A; PROJECT NO. 795; TASK NO. 342; WORK UNIT ACCESSION NO. R2

11. TITLE (Include Security Classification)
Bradley Fighting Vehicle System Combat Effectiveness: Evaluations of Developments in Tactics, Training, and Equipment

12. PERSONAL AUTHOR(S)
Rollier, Robert L.; Salter, James A.; Graber, Jon G.; Roberson, Paul R.; (Continued)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 85/01 TO 85/12	1988, August	103

16. SUPPLEMENTARY NOTATION Contracting Officer's Representative: Seward Smith.
This report satisfies the requirements for Deliverable 11-3 and Deliverable 11-5 of the subject contract.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
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			Bradley integrated sight unit; Bradley troop compartment
			Infantry fighting vehicle (Continued)

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Seward Smith	22b. TELEPHONE (Include Area Code) (404) 835-5589 22c. OFFICE SYMBOL PERI-IJ

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

i

89 8 28 78

ARI Research Note 88-116

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18. SUBJECT TERMS (Continued)

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Night operations	Scale targets	25-mm ammunition
Scale ranges	Thermal sight	Tactics
Leadership	25-mm cannon	Training

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August 1988

United States Army
Research Institute for the Behavioral and Social Sciences

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U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

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Research accomplished under contract
for the Department of the Army

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BRADLEY FIGHTING VEHICLE SYSTEM COMBAT EFFECTIVENESS: EVALUATIONS OF DEVELOPMENTS IN TACTICS, TRAINING, AND EQUIPMENT

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BRADLEY FIGHTING VEHICLE SYSTEM COMBAT EFFECTIVENESS: EVALUATIONS OF DEVELOPMENTS IN TACTICS, TRAINING, AND EQUIPMENT

INTRODUCTION

The Bradley Infantry Fighting Vehicle

The Bradley Infantry Fighting Vehicle (BIFV) is a vital element in the AirLand Battle conceptual approach to combat. The BIFV is designed to replace the M113 personnel carrier in the mechanized units of the U.S. Army. The M113 has been a "battlefield taxi," carrying troops to the battle where they dismount and perform in defense of tanks and other vehicles, or in the traditional role of the infantry foot soldier. The M113 falls short of meeting the requirements of the modern battlefield. Among numerous other shortfalls, it is too slow to keep pace with modern armor and too lightly armed to defeat the Soviet Union's main personnel carrier, the BMP.

The Bradley was designed to provide the capabilities the M113 lacks. It carries a nine or ten-man squad and is capable of speeds in excess of 40 mph on roads and cross-country. In addition, and of great importance to its combat effectiveness, the BIFV carries its squad under sophisticated space laminate armor protection with the covering support of three major turret weapon systems.

Mounted on the Bradley's two-man turret is the M242 25mm main gun which fires both High Explosive Incendiary-Tracer (HEI-T) and Armor Piercing Discarding Sabot-Tracer (APDS-T) ammunition. It is capable of destroying lightweight vehicles and carriers, including the BMP, at ranges of nearly 3000 meters. The turret stabilization system allows the 25mm gun to be fired while the BIFV is moving.

To the right of the 25mm gun is the M240C 7.62mm coaxial machinegun, which is effective against personnel targets out to a range of 900 meters. Additionally, the Bradley carries a dual tube TOW missile launcher. The launcher, hinged to the left side of the turret, folds flat for traveling and is raised through a 90-degree arc for firing. The TOW system is capable of defeating tanks at ranges in excess of 3000 meters. A further turret system consists of eight directionally mounted smoke grenade launchers, which provide concealment for the BIFV when fired. An engine smoke screen generator also aids the BIFV in providing its own security.

The Bradley carries six M231 5.56mm Firing Port Weapons, two each on the left and right sides, and two in the rear ramp of the vehicle. These weapons give the troops inside the vehicle a close-in suppressive fire capability while on the move. The overlap provided by the seven firing port vision blocks affords observation and enhances local security. The firing port weapons permit the infantrymen to fire while avoiding direct bodily exposure to enemy fire. When the tactical situation requires a dismount, the vehicle and its firepower provide covering fires for the dismounted element.

An important advance brought to fighting capability of the United States Army by the BIFV is its ability to navigate at night, and to acquire and kill targets under conditions of limited visibility. The Bradley is equipped with a

single sighting system, the day/night integrated sight unit (ISU), for all three major weapons. The sighting system operates at a 4x magnification for scanning and target detection and at a 12x magnification for target engagement. The thermal imagery system allows heat detection under limited visibility conditions. A direc+ optical relay permits the Bradley commander to override the gunner and enga targets from his station as necessay.

In summary, the BIFV is not a new "battlefield taxi." Its speed and mobility permit it to maneuver as an essential part of the Combined Arms team; its firepower can be employed effectively in an anti-armor, anti-vehicular role; the coaxial machinegun and firing port weapons enhance effectiveness in mounted operations; the infantry element can conduct dismounted operations utilizing organic dismounted weapons with vehicular support and thermal and night vision devices allow target detection and engagement under limited visibility conditions. The Bradley, thus, represents a significant advance in technology for the U.S. Army. As a result, however, the fielding of the versatile Bradley has required revisions in Infantry tactics and techniques, training and training methods. The system, with its man-machine interface, is a fertile field for research designed to maximize the combat effectiveness of vehicle and crew.

Since 1975, the Army Research Institute has contributed to the U.S. Army Research program to develop and refine this new system. Early work included human factors evaluations of prototype vehicles and task analyses to identify special aptitude requirements for crew members. Further task analyses, conducted at the request of the U.S. Army Infantry School, resulted in preparation of a set of Procedures Guides for Bradley Commanders, Gunners and Drivers, identification of leader tactical training device requirements, and recommendations for a Bradley Leader Tactical Trainer.

Most recently, as Bradley vehicles began to be introduced to combat units, the need to evaluate tactical doctrine, operational effectiveness, and training in a systems context became apparent. A program to identify emerging areas of concern and approaches to implementing improvements was instituted. The history and accomplishments of this recent work are summarized below.

The Army Research Institute BIFV Project

Background

On 31 May 1983, the Director of the Training Technology Activity, Office of the Deputy Chief of Staff for Training, U.S. Army Training and Doctrine Command, The Assistant Commandant of the U.S. Army Infantry School (USAIS) and the Commander of the U.S. Army Research Institute were signatories to a Memorandum of Understanding which established responsibilities for coordinated efforts to examine and evaluate the currently evolving doctrine, newly developing equipment, potential performance aids and training programs for the Bradley Fighting Vehicle System (BFVS), with special emphasis upon fighting at night and in daytime limited visibility situations.

The memorandum further stated that the overall project was intended to result in useable products for the Infantry School resident BIFV courses and

BIFV units. To this end, specific developmental projects undertaken were to be identified through joint discussion with and the agreement of the Project Officers appointed by the three agencies. In this memorandum, the U.S. Army Infantry Center/School and the Army Research Institute Fort Benning Field Unit are identified as user/proponent organizations.

With funding furnished by the Training and Doctrine Command (TRADOC-TTA) and personnel, equipment and facilities provided by the US Army Infantry School, the Army Research Institute, Fort Benning Field Unit, inititated a contract with Litton Mellonics Systems Development to implement the provisions of the Memorandum of Understanding. The contract was approved for execution on 1 September 1983.

Project Plan

The overall project was divided into two phases. The objective of the first phase was to conduct a broad-base analysis of BIFV doctrine, equipment, and training. The analysis was designed to collect data for constructive definition of deficiencies and issues, and to recommend actions (and action agencies) to develop solutions to these problems. Emphasis was to be placed upon night and limited visibility training and operations in this phase.

The follow-on phase of the project began in the second year. This was an experimentation and test phase, building upon the initial problem analysis. Selected potential improvements in techniques, equipment, training and gunnery (addressed to high priority needs identified during the problem analysis phase) were developed further and evaluated by the ARI/Litton research team.

Overview of the Problem Analysis Phase

Full details of the results of the first-year effort were documented as working papers in September, 1984, and reissue of this material as an Army Research Institute Research Note is in preparation (See Bibliography). A summary of the first phase of the project is presented here as additional background for the present report.

Approach for the Problem Analysis Phase

The ARI/Litton research team initiated work with a multidimensional examination of the doctrine, tactics, techniques, equipment and training of mechanized forces in the day, night, and limited visibility environment. The focus of this first phase was to identify observed or emergent problems, or shortcomings in tactics, equipment or training; then to define doctrinal, equipment or training solutions--or determine problems and approaches suitable for subsequent test and evaluation.

The individuals assigned to the BIFV research team possess behavioral science expertise and/or prior military experience with the BIFV and precursor

vehicles such as the M113 and the MICV (Mechanized Infantry Combat Vehicle). This experience base assisted development of a thorough understanding of the new BIFV system.

Multiple approaches to problem analysis were utilized. In order to understand and place in perspective the requirements, techniques, and special knowledge required for limited visibility operations, it was first necessary to assimilate the BIFV data for daylight operations. In large part, limited visibility activities are based upon modification of daylight procedures, tactics, techniques and doctrine. Further, tactical operations can shift to the limited visibility mode v ̇.y rapidly.

Soviet equipment, organization, doctrine, tactics and techniques were studied as the primary Threat against which U.S. training and operational requirements should be measured, since most Bradley-equipped units will be assigned to USAREUR or as replacement units to USAREUR.

Squad member duty performance was assessed, especially in the use of surveillance, target acquistion and night observation (STANO) devices. The different devices available to field units were examined as to their basis of issue, the potential value in the night and limited visibility environment, equipment interface issues (human factors), or training problems experienced. In addition, research agencies and technical sources were queried in regard to state-of-the-art technology applicable to BIFV limited visibility operations that may be available in the near future.

Research team members examined BIFV resident course instruction. These courses included Infantry OSUT, BIFV Gunners Course, BIFV Commanders Course, BIFV Master Gunners Course, and main stream Infantry School courses (BNCOC, ANCOC, IOBC, and IOAC). The relevant POIs, lesson plans, training texts, and training aids were studied. Field manuals, technical manuals, and other doctrinal literature serving as the reference base for instruction were analyzed, also. Staff members attended several iterations of all BIFV-related instruction and participated in a student role as appropriate. An extensive dialogue with training cadre at all levels was developed and this group served as an important reservoir of subject matter expertise during the project.

Subject Matter Experts (SMEs) throughout the BIFV community became important sources of information about problems and issues surfacing during the initial fielding of this new system. These experts were located at levels ranging from Senior NCO instructors through the Department of Defense. Research team members pursued extensive interaction with individuals and groups assigned to revise existing reference material by incorporating material specific to the BIFV, or to develop original BIFV field manuals, technical manuals, training circulars and other doctrinal documents. In the equipment area, both users and manufacturers were tapped for information concerning expected capabilities and actual typical performance achieved by soldiers. Anecdotal evidence and numerical data accumulated by the New Equipment Training Team (NETT) was probed. Dialogue with military and civilian scientists at the PMO-BIFV and TRADOC levels continued throughout the life of the problem analysis phase.

On-site observations of the activities of BIFV-equipped units in CONUS and Europe were conducted by ARI/Litton staff members. An observation protocol that paralleled elements of Army Training and Evaluation Programs (ARTEPs), applying to BIFV or M113 platoon or squad, was developed and used to record observations in the field. During the USAREUR trip, the BIFV research team observed the conduct of an ARTEP for a BIFV battalion and an M113 battalion in a mid-winter exercise at a major training area. Each team member rode in the troop compartment with a squad 24 hours a day for 9 days. This procedure was duplicated during a 7-day Combined Arms FTX conducted at a major CONUS training facility. A third opportunity to observe BIFV unit operations arose as a result of a special operational test planned and conducted by the USAIS (Operation Eagle). The tactical exercises included an 8-day force-on-force exercise and a 2-day combined arms live fire exercise. The combined observations from the three sites provided data relevant to tactical operations of BIFV and M113 battalions in extended field environments under varying conditions of weather, terrain and visibility. Because of the variety in locales visited and types of exercises observed, research members were in a position to note BIFV crew member performance under conditions of adverse weather, fatigue, equipment failure, and prolonged confinement within the BIFV. The observations formed the basis for analysis of doctrine, techniques, and BIFV gunnery, with special focus on employment of STANO devices.

Finally, an extremely important aspect of the multidimensional approach involved coordination with technical agencies, participation in seminars, briefings and workshops, and frequent interaction with the proponent. Through this philosophy and practice, ARI/Litton research team members were able to assimilate the technical and tactical details of the new BIFV system, remain current with emerging developments relevant to the BIFV throughout the military community, and perform an influential role in disseminating information about urgent problems and issues.

The data accumulated through these multiple approaches provided the basis for identification of substantive problems and issues associated with the fielding of the new BIFV system.

Problem Identification

During the first year (Phase I), each of the major areas investigated by the research team identified problems and unresolved issues which impact on the combat effectiveness of BIFV units. The overall results were divided into eight major areas. These elements are:

- The Threat;
- Surveillance, Target Acquisition and Night Observation (STANO) Devices;
- Friendly Element Identification;
- Human Performance Under Night and Limited Visibility Conditions;
- Mechanized Infantry Training Provided by USAIS;
- Field Observations;
- Directed Energy Activities;
- BIFV Equipment Deficiencies.

After delineation of the problems, the research team completed the first phase of this project by developing recommendations for actions to address the issues. Each identified problem was matched with an agency which had cognizance or responsibility for corrective action. Direct solutions were defined where possible, and problems requiring further examination, research or test were isolated as directions for further research. Over 100 separate deficiencies, and associated potential solutions, were detailed and disseminated. Of the total, the ARI research team was designated as the appropriate action agency for 46 items, to act either solely or in cooperation with a proponent agency (e.g., USAIS).

The Development and Evaluation Phase

Although the first year of the project (Phase I) was intended to examine the current status of equipment, training, operations and doctrine for newly constituted BIFV units, emphasis was to be placed upon the status of these areas under night and limited visibility conditions. Almost from the outset it became apparent that units and service schools were so engrossed in establishing basic tenents for this new and revolutionary mode of infantry warfare that more advanced and sophisticated procedures would have to await the development of the basics. Only after fundamental precepts for use of the mobility, firepower and lethality of the BIFV had been incorporated in field manuals and training texts would it be possible to give serious consideration to special operational environments.

BIFV units were experimenting with mounted maneuver, massing of vehicular fires and development of combined arms procedures for joint field operations with armored and artillery units. Even field training exercises which required use of dismounted infantry elements were of less than critical importance to BIFV tactical units. Therefore, night and limited visibility operations, considered to be more complicated and thorny issues, were relegated to the "back burner" until the resolution of fundamental problems could be effected.

Service Schools experienced the same difficulties as BIFV units. Initial reaction to the advent of the BIFV consisted of steps to convert manuals and texts written for the M113 into guidance for a brand new weapons system. In addition, since no instructor or writer had ever been given the opportunity to ride in, fire, or serve in BIFV-type vehicles or units, there was no real data base, experiential background or other frame of reference for development of operational, training or doctrinal guidance for tactical units.

Neither tactical units nor training institutions could have done better. Staff officers, instructors and field commanders alike exercised an exceptional amount of initiative in order to meet highest priority issues first. The dramatic growth of a training, doctrinal and operational guidance program for a completely new conceptual approach to infantry warfare is due, almost exclusively, to these pioneers. The ARI BIFV research team, along with New Equipment Training Teams (NETT), the TRADOC Systems Analysis Activity (TRASANA), and the TRADOC Combined Arms Test Activity (TCATA), participated in the initial training and operational guidance effort.

As part of its initial survey of the existent status of training, doctrine, and operations, the BIFV research team identified a number of problems that existed for both day and night activities. From this list of candidate research subjects, ARI, in coordination with the Infantry School, nominated a number of major areas as meriting further study or test. Indeed, the group of subjects that could be addressed constituted a larger menu than could be pursued within the scope of the second year (Phase II) of the ARI/Litton project. Therefore, a specific and manageable list of candidates was selected for Phase II research.

These subjects were screened to include sufficient research into the night and limited visibility environment to comply with the original contractual guidance to the maximum extent possible. At the same time, there were a number of subjects which due to their importance required an immediate research effort. Subjects selected consisted of the following:

- Platoon/Squad Leader Span of Control;
- Continuous Operations;
- Ammunition Handling/Storage Equipment;
- Troop Compartment Visibility;
- Friendly Vehicle Identification;
- Individual Crew Member Equipment;
- Thermal Mode of the Intergrated Sight Unit;
- The Bradley Commanders Course;
- Night/Limited Visibility Training;
- Through-the-Sight Video;
- Scale Vehicles/Ranges;
- Gunnery Procedures and Training.

This report is one of two companion publications that document the details of work completed during the test and evaluation phase. The sections of this report which follow treat each of the topics above, except the last topic listed. Gunnery Procedures and Training encompasses so many discrete issues that it is treated as a separate but contemporary report. However, the two reports represent documentation of the work completed under this contract.

With the publication of this report, ARI/Litton has researched, developed, tested and documented a significant number of potential solutions to complex problems associated with the fielding of a totally new weapons system. In the process of this effort a major data base has been created which will permit investigation of more complex and untested conceptual approaches to equipment improvement, target surveillance and acquisition, advanced thermal

training procedures, use of scale targets and ranges for sustainment gunnery training (both night and day/limited visibility), combat loading, and training device development and testing. These activities will constitute research to be conducted over the next two-year period.

Report Organization

The organization of this report employs a general format for each separate section devoted to a topic. The first portion of each section defines the specific problem(s) identified during the problem analysis phase. Next, the analytical approach utilized by the ARI/Litton research team to develop one or more solutions in this problem area is described. Following this is a description of any developmental work that was required to obtain operational products or prototypes for testing. The evaluation methodology employed to validate the effectiveness of products or prototypes is summarized. (As appropriate, additional technical details which amplify the topic summary presented in the body of this report are made available in an associated annex). Finally, each section is completed with a discussion of results and detailed recommendations concerning directions for future work in the problem area.

BIFV TACTICS AND TECHNIQUES

Overview

This section presents work performed by the ARI/Litton research team in the area of BIFV operations. The versatility of the Bradley personnel carrier/weapons platform has had a dual impact on emerging infantry doctrine. On the one hand, a new weapons system such as the Bradley can be employed to enhance performance of conventional infantry tasks, given crew mastery of established tactical doctrine and preparedness to fully utilize the state-of-the-art technology. On the other hand, the Bradley has capabilities that can be used to accomplish the infantry mission through employment modes that are very new to the infantry. The latter requires the development of new tactical concepts, procedures and techniques.

The delivery of BIFVs to units and the development of new concepts for employment have proceeded concurrently. During on-site visits to USAEUR and CONUS BIFV units, the research team noted that there had been progress in the areas of maintaining the vehicle and exercising the raw capabilities for fire and maneuver. However, development of new or modified tactical guidance for operational employment of these capabilities, particularly at the levels of company/platoon/squad, had not kept pace.

Upon completion of the problem analysis phase of the project, the BIFV research team presented 40 specific recommendations related to BIFV tactics and techniques (see References). The identified action agency for these items was either the US Army Infantry School or the Army Research Institute. Some of the recommendations could be implemented with very minimal preparatory work. Other recommendations targeted the need for future work to develop and evaluate candidate solutions to major tactical issues; the latter type of recommendation became a prime area for consideration in the second year scope of work.

Typically, research and development work in the areas of tactics and doctrine requires enormous expenditures of assets when conducted on a full-scale basis. Dedicating one vehicle for one hour to investigation or test activities, represents allocation of cost items such as POL, ammunition, maintenance hours, and crew member man-hours. Utilizing a full BIFV platoon represents more than just a four-fold increase in assets required. Employment of a company sized unit multiplies the cost even more. An indirect cost is always involved because the assets cannot be used for other purposes such as training support during the time they are employed in research activities.

These constraints impacted upon the process of selecting a manageable number of research topics from the list of 40 recommendations, as the most critical items for inclusion in the second year scope of work to be conducted by the ARI/Litton research team. During a July, 1984 In Process Review conducted for the CG, USAIC and Commander, 29th Infantry Regiment, eight candidate tactical studies were presented for consideration. These were:

- Preparation and Occupation of BIFV Platoon Defensive Positions;
- Squad Leader Span of Control;
- Platoon Leader Span of Control;
- Employment of BIFV after Dismount;
- BIFV Unit Artillery Support;
- Use of FIST/FO;
- Battle Captain/2IC Concept;
- BIFV Fire Support of Dismount Element.

Of these candidates, approval was recieved for investigation of squad and platoon leader span of control in a field tactical test. This area was selected for further work during the second year of the project because of the criticality of this issue to doctrinal development. The remaining areas were acknowledged as important topics that should be pursued as additional assets become available.

A second area addressed in this section focused on the techiques for countering the effects of mental and physical fatigue that develop in unit personnel involved in continuous operations. Coordination with users and proponents indicated the need for development of unit SOP to implement known techniques for surviving and fighting during periods of prolonged active combat. It was determined that this could be accomplished by the ARI/Litton Research Team within the scope of the project.

The ARI/Litton work that was performed in the areas of tactics and techniques during year 2 is reported in the following subsections. These subsections give definition of the problems addressed, the approach adopted by the research team, and conclusions and recommendations for implementation.

Problem Definition

Leaders of Bradley units must master two skill dimensions. First, they must master all the skills required to wage war in the traditional infantry role. Second, they must know armor tactics, techniques and equipment in order to conduct the mobile type of war that will be required in the future. In particular, BIFV squad and platoon leaders also must master the tactics and techniques required to perform as leaders in combined arms teams of varying composition. These may be either armor-dominant in composition and employment, or infantry-dominant but with armored elements in support. Requirements may be dramatically different dependent upon both task organization and tactical concepts employed.

The BIFV, itself, introduces new requirements on leaders for mastery of maintenance and employment skills for the vehicle, its weapon systems, and an array of other equipment. This mastery demands technological competence and tactical acumen. A single BIFV possesses more firepower potential than that found in the standard dismounted, or non-mechanized infantry platoon. The weapons systems aboard the vehicle include sophisticated sighting equipment for use during both daylight and limited visibility conditions. The TOW missile system integral to the vehicle can destroy tanks and other vehicles at distances beyond 3.5 kilometers. Other weapons that are assigned to each vehicle include antitank weapons such as the LAW and Dragon, antipersonnel and antitank mines, M-60 machine guns, squad automatic weapons (SAW), and six firing port weapons mounted to the flanks and rear of the vehicle. An organic smoke producing capability can obscure significant areas of the battlefield either singly or in concert with other similar vehicles.

Personnel assigned to the BIFV include a mounted element consisting of a driver, commander and gunner, and a dismount element of six men organized as a fire team. Both squad and platoon leaders must be capable of operating as leaders of the dismount force when it is deployed. The requirement also exists to fight the vehicle with the dismount element aboard or deployed, as well as to furnish fire support for a single squad or in support of the entire BIFV platoon.

Infantry squad and platoon leaders must master a wide variety of skills in addition to the above to be effective in combat. These leaders and their units may be called upon to emplace or reduce obstacles and minefields, perform mounted and dismounted land navigation, recognize and react to enemy personnel and equipment (with appropriate responses being critical to survival), perform specialized tactical missions in a wide variety of terrain and environments, call for supporting fires from artillery, air and sea resources, survive and fight under nuclear, chemical or biological conditions, perform first aid, utilize sophisticated infra-red, sonic, laser, and ambient light devices, and know the tactics and techniques required to fight in urban areas, forests, jungles, deserts and frigid artic wastes.

All of the above requirements for competence, proficiency and ability must be developed within an individual who has already demonstrated a significant

degree of leadership and maturity. Leadership of men demands a knowledge of and sensitivity to human relationships. Good leaders must be compassionate as well as tough, caring as well as competent, and charismatic as well as exemplary in their own conduct.

The vicissitudes of combat also demand leaders who can remain calm in the face of danger, respond logically in periods of crisis and make rational decisions while tired, hungry, fearful, and emotionally spent. The maturity required to exercise control over other personnel under these conditions is significant.

The question as to whether the Bradley Infantry Fighting Vehicle (BIFV) squad and platoon leader will be able to perform all assigned duties in a crisis environment, without experiencing significant task overload, has arisen. Reports and observations from BIFV units, field research agencies and Subject Matter Experts (SMEs) as well as queries from senior Army personnel provide impetus for investigation of this question. The concern would appear to be a legitimate one in view of the many new and complex tasks the BIFV leader must now perform in addition to performance of the traditional duties required of infantry squad and platoon leaders.

During the problem analysis phase, the research team observed tactical units engaged in major field exercises in both Europe and CONUS. These observations indicated that there were numerous control difficulties experienced by squad and platoon leaders within newly created BIFV units. These difficulties included tactical leadership errors of omission and commission. Subsequent observations by members of the USAIS directorates and other military personnel tended to confirm original observations and indicated little progress had been made in correction of these deficiencies.

However, the research team interviewed a number of SMEs who contended that the introduction of the BIFV has not resulted in significant increases in the duties of squad and platoon leaders.

This group believes that with the introduction of a new infantry fighting vehicle there has been a concommitant increase in trained personnel that the leader can assign to perform the new duties. For example, the gunner discharges the functions of gunnery; the driver performs both as operator of the vehicle and as maintenance specialist--aided by the entire dismount element of the squad; all firing port weapons are manned by the dismount team under the supervision of the assistant squad leader; and, most important, the assistant squad leader replaces the squad leader in the turret when the squad leader is absent or dismounted to command the dismount element. The platoon leader, too, has a driver, a gunner and a replacement commander for the vehicle whenever the platoon leader must dismount. In addition, the platoon leader's mounted responsibilities for command of the four BIFVs are assumed by the platoon sergeant whenever the platoon leader dismounts.

Given that SMEs within the Bradley community are divided on this issue, it was considered appropriate to investigate whether the advent of the BIFV and its ancillary equipment has created a set of conditions under which leaders are no longer able to perform all traditionally assigned and newly emerging duties. Recent concerns about whether the BIFV squad and platoon leader can dismount to

lead dismounted elements and still retain responsibility for directing the fires of the BIFV(s) assigned to their elements is a further impetus to the need for investigation.

The ARI/Litton BIFV Research Team recommended conduct of a field test to examine the issue of span of control for BIFV squad and platoon leaders. In July 1985, during the course of an In Process Review (IPR) conducted for the Commanding General of the Infantry Center and for the Commanding Officer of the 29th Infantry Regiment, this recommendation was approved as a topic area for work in the second year of the project.

Objectives

The objective was to observe, measure and record the actions of BIFV squad and platoon leaders in an extended tactical environment which, to the degree possible, replicates the crisis conditions of combat. The observations would focus upon the true magnitude of the span of control requirements for BIFV platoon/squad leaders and whether it is realistic to expect that well trained BIFV leaders can cope with this task load. This test provided for observation and measurement of BIFV squad and platoon leader reaction to realistic tactical stimuli in a field environment. Observations and measurements obtained would be analyzed to determine whether these leaders are able to perform required combat duties over extended periods of time. Results obtained will serve as a base for more sophisticated subsequent testing of similar tactical elements in major field exercises. However, data obtained in this test phase would provide meaningful insights about the maximum span of control of tested leaders and perhaps result in identification of both procedures and techniques to assist such leaders in duty performance.

Method

The design of an appropriate, controlled, field exercise in which to pursue the objective was aided by experience gained during ARTEPs previously observed in Europe and CONUS, by discussions with SMEs from USAIS and BIFV tactical units, and by review of existing training literature from a variety of sources. The research team balanced the competing requirements to: (a) design a test environment that would optimize collection of objective and comprehensive data; and (b) ensure that the scope of the planned research did not exceed practical considerations of availability of vehicles and personnel. The major elements of the methodology included development of tactical scenarios for a field exercise that would bring the leader span of control issue into play, preparation and rehearsal of an observer team and chief controller, and development of data collection instruments.

Tactical Scenarios. The field test was determined to require at least two days of continuous operations to introduce the proper degree of exhaustion and stress. Tactical scenarios were developed which would elicit the types of responses required to measure abilities of leaders in performance of required tasks. It was concluded that four tactical situations could provide sufficient leader action to measure the preponderance of the skills required. The four scenarios are: (a) movement to contact/hasty attack; (b) hasty defense;

(c) delay; and, (d) deliberate defense. Each of these situations would require resolution of tactical problems posed by terrain, weather, equipment and effective utilization of an aggressor force as a training aid.

In brief, the 3-day plan for the exercise followed the schedule below:

DAY 1	Assembly Area Movement to Contact Limited Objective Attack Hasty Defense
DAY 2	Receive Order for Deliberate Defense Move and Prepare Deliberate Defense (0700) Conduct Defense (1700 Receive Order for Delay in Zone--Approximately 2200 Start Delay Operation)

DAY 3	Delay; (2200-0600)
	Delay from 3 Positions
	Hasty Defense (0600-0900)
	Patrols & Probes--Day and Night
	Receive Order for Conduct of Deliberate Defense
	Prepare Deliberate Defense
	    Receive Aggressor Fires and Attacks
	    Repel Attack
	    Reorganize and Consolidate
	Terminate Problem--1600 hours

Test Units and Exercise Site. The site available for the exercise was a local maneuver area eleven kilometers long by six kilomenters wide (Fort Benning Training Area Oscar). This area provided the space and variability in terrain required for realistic implementation of the tactical scenarios.

A platoon from Delta Company, 1st Bn, 29th Infantry Regiment served as the friendly force. Two additional squads from Delta Company performed as the Opposing Force (OPFOR). All personnel were briefed on the purpose of the exercise.

Observation Procedures. An observer was assigned to the platoon leader vehicle and one observer to each of three squads. The chief controller monitored the exercise from his vehicle. An additional research team member was assigned to the Tactical Operations Center (TOC). All research personnel on-site had prior military experience and BIFV-specific expertise. Observers neither interfered with nor advised the platoon leader or squad leaders. Observation was continuous from start to finish of the exercise.

The most critical task was to prepare check sheets (observation protocols) which would permit appropriate observation of the leadership actions, interactions and reactions to specific tactical conditions. Span of control, for the purpose of this test, referred to the ability of the squad and platoon leader to perform all assigned duties in a crisis situation without experiencing significant task overload.

The items measured by the checklist included: (a) leadership--primarily the ability to understand orders and to give an understandable order during a crisis situation; (b) job knowledge--the technical and tactical proficiency necessary to perform a variety of missions; (c) maintenance--the ability to supervise necessary maintenance of the BIFV and ancillary weapons systems; (d) tactics--knowledge of the tactics of mechanized infantry and of the techniques necessary for their implementation.

The checklist measured leader performance during each tactical operation conducted during the exercise which consisted of: (a) tactical road march; (b) assembly area procedures; (c) limited objective attack (in conjunction with a movement to contact); (d) hasty defense; (e) deliberate defense; (f) delay in zone. The content of the checklist was drawn from ARTEPs, input from subject matter experts, input from cadre of BIFV units, and research team command experience. Observers were extensively rehearsed in the use of the checklist prior to the operation. The observation protocols used are available.

Satellite Tests. The BIFV Research Team determined that it was possible to maximize the use of the assigned troops and equipment by simultaneously testing many concepts and items of equipment. Priority was given to examination of squad and platoon leader reaction to tactical situations, and no interference with this aim was allowed. However, the major test aim of investigating platoon/squad leader span of control could be accomplished with efficient use of test resources to simultaneously evaluate the following items of equipment: (a) a new combat vest and pack for use by BIFV infantrymen; (b) new infrared pulse devices (trade name, Fireflys); (c) new night vision goggles sensitive to both infrared and ambient light (designed by the Wild Corporation of Switzerland); and (d) a new transparent cargo hatch cover developed by ARI/Litton to provide improved security and passive air defense. The description of the purpose and results of these satellite tests are treated in Appendix E of Rollier, Roberson, et al., 1988.

Exercise Results

The field test created the environment which was necessary to establish tactical conditions under which measurement of squad/platoon leader span of control was possible. The three-day duration of the test and the rapidity of tactical events give valid indicators of leader performance under stressful and fatiguing conditions. The results of consolidation and analysis of the checklist observations indicate that the leader errors of commission and omission which did occur are not attributable to an excessive number of leadership requirements. The errors relate more to gaps in job knowledge than to lack of sufficent time or resources to respond to developing tactical requirements. The results should be interpreted in light of the fact that the test platoon was a TDA unit, having the primary mission of supporting the Infantry School. The platoon leader, squad leaders and troops had little previous opportunity to train as a tactical unit. A general observation was that leader capacity to perform all required tasks in a timely fashion, improved over the course of the exercise, indicating that practice over time has a much stronger positive effect than the potentially degrading effects of fatigue and task overload.

The information recorded by the team of observers and the chief controller support the following conclusions:

- The tactical test provided an adequate basis for measurement of the critical span of control issues;

- The tactical setting and duration of the exercise were sufficient to simulate the combat/stress conditions desired;

- There was no specific area of measurement in which leader performance errors could be attributed directly to fatigue, stress or preoccupation with other critical tasks;

- Failures of omission or commission appeared to be reflective of knowledge deficiencies or memory failure, not of lack of time or crisis invoked situations;

- Current duties assigned to BIFV squad and platoon leaders are considered to be well within their capability and capacity;

- There is a need for a functional Combat Leader's Guide, designed to provide "checklist" formatting of leader duties by subject areas.

- There is a need for simplified tactical training scenarios that:

  (1) expose leaders to tactical leadership requirements and principles while participating in a walk-through situation (TEWT);

  (2) permit detailed observation of student performance and extensive post-scenario critique.

Recommendations

Based upon the information acquired during the course of research into the issue of leader span of control, the following recommendations are made for improvement in leader training:

- Development of a Combat Leaders Guide for use by BIFV Squad and Platoon Leaders;

- BIFV Tactical Exercises Without Troops (TEWT) should be developed and used in instruction of BIFV leaders in resident instruction at USAIS and in BNCOC, ANCOC and BIFV career development courses;

- New tactics be created to include provision for those conditions under which squad leaders will be required to both direct the maneuver of the squad dismount element and the fires of the squad BIFV.

Problem Definition

The lessons learned from past conflicts include periods of combat which have become known by the term "continuous operations," during which US Army units have performed combat tasks round-the-clock, without respite for periods of weeks or months. Continuous operations encompass, of course, not only active contact with the enemy, but also planning/preparation for engagements and reorganization after operations.

Portions of the work performed by the ARI/Litton research team during the problem analysis phase addressed the issues of continuous operations that impact specifically upon BIFV units. One approach involved the review of literature pertaining to Threat doctrine for future conflicts. A second literature area focused upon research into the potential degrading effects of continuous operations on task performance, and measures for countering these detractors. This background information was utilized by research team members during observation of BIFV unit operations in the field.

Concepts for Army 21 support the conclusion that periods of continuous operations will be highly probable in future conflicts. For example, Soviet doctrine indicates that they will attempt to use shock and constant pressure as offensive weapons. Also, early successes in the initial stages of future conflicts will be even more critical for the eventual outcome than in the past; therefore, US units must be prepared, at the outset, to react to prolonged enemy offensives and to capitalize upon its own successes.

The military lessons learned point out that the task performance of even the best-trained individuals becomes degraded in the latter stages of continuous operations. Continuous operations are characterized by conditions of task overload, physically debilitating environments, fatigue/sleep loss, and exposure to life-threatening situations. These major contributing causes of performance degradation have a combined effect at any given time and are progressive in intensity over prolonged exposure.

There is an extensive body of basic research that has investigated the aspects of tasks that are most susceptible to the degrading effects of continuous operations. In general, effects occur earliest for tasks requiring perceptual speed and visual acuity, fine motor skills, memory, reasoning/decision making, vigilance, or communication/interaction with team members. The Army Research Institute has performed extensive work in this area that resulted in the publication of militarily-oriented guidelines for conteracting the effects of continuous operations on the most susceptible combat tasks (see Graber & Rollier, 1986a).

During on-site visits to BIFV units in USAEUR and CONUS, research team members observed ARTEPs spanning a nine-day period. The nature of the exercises was such that many of the characteristics of continuous operations were realistically created. Observers were prepared to take advantage of this

opportunity and the consensus conclusion was that there is a general lack of awareness, within BIFV units, of the lessons learned pertaining to continuous operations. Observers experienced first-hand the effects of confinement within the BIFV troop compartment for periods up to eight hours. Over time, the troop compartment itself can become a debilitating environment for an individual, through the accumulated effects of crowding, vehicle motion, fumes, and psychological reactions akin to claustrophobia stemming from combat anxiety and uncertainty about conditions existing outside the vehicle at any given time. Measures to counter these effects were non-existent or haphazard from one vehicle to the next.

Additional information was developed through observation of the behavior of leaders over the course of the exercise and leader replies to queries related to continuous operations issues. Both leader behavior and leader opinions indicated the widespread existence of counterproductive attitudes about leadership requirements during continuous operations, and/or gaps in knowledge of measures for countering debilitating effects upon their troops and themselves.

For example, junior leaders became progressively exhausted in the latter stages of exercises as a result of failure to sleep when the tactical situation would have permitted this. A platoon sergeant was observed to act as the vehicle commander during the entire four-day exercise with only four hours of sleep, despite the fact that he had a qualified commander in his vehicle. In another example, a platoon leader fell asleep from exhaustion while his unit was occupying a defensive position. He did not awaken until the enemy was on both flanks of and behind his position. His desparate reaction was to lead his unit out of the area at speeds which could have produced accidents and endangered the entire command. The ARTEP controllers failed to properly declare the platoon a casualty and the opportunity to relate the incident to the issue of sound sleep procedures for leaders was overlooked in the ARTEP evaluation.

Further investigation by the observers indicated that senior commanders wanted junior leaders instantly available and ready for rapid reaction. Subordinate leaders' perception of this attitude caused them to ignore normal sleep procedures and, as their exhaustion increased, so did errors of ommision and commission. Fatigue accounted for failure to dismount personnel in appropriate situations, to provide adequate warnings on the tactical situation to subordinate leaders, and to capitalize on tactical situations.

In short, it appeared to be the belief among leaders at all levels that they should "tough it out" until the end of the exercise, and that implementing measures designed to counteract the effects of continuous operations, for themselves or their troops, would be considered substandard leadership behavior by their immediate superior.

The Army maxim of training the way it will have to fight applies to the issue of continuous operations. The observed lack of readiness on the part of BIFV units for fighting under these conditions qualifies this as an area of prime concern; it was selected by the ARI/Litton research team for further development and evaluation during the second year of the project.

Approach

The research team re-examined the literature having relevance to continuous operations conducted by BIFV units. Current training practices in resident BIFV-courses and in the units were analyzed to isolate instructional content and pratical exercises which would prepare personnel for continuous operations. In the latter case, the void that currently exists is epitomized by the fact that BIFV resident and unit training does not emphasize the need for establishing and implementing a unit SOP (Standing Operating Procedure) for continuous operations.

Standing Operating Procedures prescribe routines or techniques for the accomplishment of duties that units or individuals will perform in essentially the same way a preponderance of the time. Within tactical units there is a document referred to as the Tactical SOP. This document is directive in nature and causes all components or sub-elements of a unit to perform combat and combat support tasks in a uniform, specific way. Examples of routines incorporated into a BIFV company tactical SOP include: dismount drills; immediate action drills; reporting; mounted combat formations; vehicle combat loading; ammunition stockage levels; resupply for Class I, III and V materials; passive and active air defense measures; and similar combat related activities.

Continuous Operations Standing Operating Procedures will be found as annexes to many battalion and brigade level SOPs, but are not existant at company level. Even when incorporated in battalion tactical SOPs, continuous operations procedures tend to be ignored in the field environment. Commanders and staff personnel alike extend themselves for protracted periods with little or no rest -- resting on a scheduled basis is unusual.

Human maintenance needs which are critical to unit combat effectiveness and performance of combat-oriented tasks receive little or no emphasis. The requirement to insure that personnel, and in particular, small unit leaders, obtain sufficient sleep to remain at a high level of efficiency over the course of prolonged combat operations is essential. Yet, little or nothing has been done to establish a routine that will cause key personnel to sleep while still insuring that their duties are performed by alternate personnel.

An effective work/rest schedule would require flexibility in scheduling. Leaders must understand the principles and human factor needs behind the continuous operations SOP. In addition, they must be able to adapt the routine as necessary in fast developing combat operations. Further, implementation of the work/rest program must be supported by leader recognition of the need for cross training of personnel so that critical skills are not lost during sleep/rest periods.

At present, neither Army Training and Evaluation Programs (ARTEPs) nor ARTEP Mission Training Plans (AMTPs) isolate continuous operations for special attention. Neither series of documents causes controllers/observers to check upon proper rest cycles as a leadership task for evaluation. Without a scoring procedure and/or a system which adds or subtracts points for (non)compliance, commanders will ignore this area or give it less attention than is required. As was pointed out earlier, going without rest for the period of a short field training exercise is not going to have the same impact as lack of rest for an

equivalent period in a combat environment. However, if the axiom "we train as we fight" has meaning, then units are not now prepared to perform for extended periods in combat.

Modification of current ARTEPs and AMTPs to include specific evaluations of how well leaders implement a continuous operations SOP would be a step forward in increasing unit readiness to fight for prolonged periods. It would be important for the ARTEP to provide scoring of Continuous Operations (CONOPs) at every tactical phase, and in every 24 hour period. In this way, commanders at squad through battalion level would see CONOPs as a scored criterion for successful exercise completion.

It was determined by the research team that the creation of a Continuous Operations SOP would have an immediate impact upon both attitudes and behavior. That is, it would both signal command emphasis on the employment of countermeasures and provide guidance on unit-wide implementation of techniques to off-set degradation of performance under conditions of continuous operations.

The ARI/Litton BIFV research team could develop a unit-ready SOP in minimal time because the composition of the team provides the requisite knowledge of the literature, behavioral science expertise, prior combat experience, and BIFV-specific expertise. To insure immediate and effective use by platoon and squad leaders, the SOP was prepared in standard military format with this audience in mind. The principles of selectivity and condensation were applied to the voluminous information available for inclusion in an SOP, to control its length and emphasize the most critical action items in terms immediately understandable by junior leaders.

Several iterations were prepared and staffed with BIFV SMEs. The version presented in the following subsection represents a trade-off between competing requirements; the need for brevity and simplicity was balanced against comprehensive coverage of the most essential measures for maintaining individual and unit effectiveness during continuous operations.

The Continuous Operations SOP

The text of the proposed ARI/Litton CONOPS SOP is presented in Graber, 1986a. A brief description is given here. A four paragraph format for a Continuous Operations annex to the company Tactical Standing Operating Procedure was employed. Paragraphs devoted to "Purpose" and "General" introduce the requirement for leaders to recognize the effects of continuous operations upon personnel in their command and the requirement for insuring that sleep discipline is enforced. The third paragraph presents a Detailed Plan for the continuous operations SOP and introduces a company-wide rest schedule. The schedule divides the day into four six-hour periods and assigns personnel in each duty position to a sleep/rest period. The two periods spanning the normal darkness hours of 2000-0800 are the primary periods with the daylight hours available as an alternative schedule if required. The assignments are based upon an underlying logic that recognizes the typical requirements of company tactical operations and insures that an alternate is avaiable to perform the most critical functions when the individual with primary responsibility is

resting as scheduled. For example, the company commander is assigned to rest during the first portion of the night while the executive officer remains awake. Individuals normally rest best during the hours of 0200-0800, but it is appropriate for the company commander to be alert during this period since it generally presents more complex tactical demands than the early part of the night (2000-0200 hours). As a further example, assignments across the three platoons are designed so that not all leaders are asleep at the same time and platoon leaders and platoon sergeants alternate sleep/rest periods. As noted in the text of the SOP, leaders may have to adjust either the sleep periods or personnel assignments as the tactical situation dictates, but the proposed schedule offers a logical approach for most situations and a framework for appropriate adjustments.

Conclusions

There is a clear requirement for increased BIFV unit awareness of the combat-relevant aspects of continuous operations. Appropriate tools for preparing to survive and fight under these conditions must be provided to units. The SOP at Annex 2 provides guidance suitable for establishing a routine work/rest schedule that units can use immediately to improve sleep discipline.

This section has described developmental work that will have an immediate impact upon units. Placing guidelines for the conduct of continuous operations in the hands of leaders at company/platoon/squad levels will increase awareness of the issue and provide a tool for immediate use.

Recommendations

It is recommended that:

- The ARI/Litton Continuous Operations SOP be disseminated to unit commanders and trainers;
- Follow-up work be planned to accumulate field comments and experiences with implementation of the SOP;
- BIFV ARTEPs be modified to permit evaluation of implementation of sound continuous operations procedures and penalization of individuals and units that fail to conform.

BIFV EQUIPMENT

Overview

The Bradley is a very complex system with many points where the man-machine interface impacts critically on mission success. During the problem analysis phase of this project, the BIFV research team cataloged all instances where performance of an equipment-aided task was at generally unacceptable levels in BIFV units. Then, a number of approaches were used concurrently (and on a case-by-case basis) by the research team to build the data base for recommended solutions to equipment-related problems.

A precise definition of each problem was formulated to pinpoint why and how the performance of an equipment-aided task was currently inadequate to meet combat requirements. This served as identification of the objectives to be met by future work to develop solutions.

Team members acquired extensive hands-on experience with the equipment organic to the Bradley and this preparation enabled the staff to take a user-oriented point of view when analyzing the performance deficiencies that were identified through field observations and participation in BIFV-specific training. Also, user comments were solicited because a user often can relate the difficulties encountered in task performance to inadequacies in the training he has received, to detractors related to the way the task is currently being performed, or to deficiencies in the equipment itself.

The next step was to assess the major contributing causes for an observed performance deficiency, to determine whether solution development should focus on: (a) changing current equipment configuration; (b) modifying the procedures currently being taught for the use of the equipment as is; or, (c) improving the training currently given to users.

The ARI/Litton research team identified a number of solutions based on modification of, or addition to, the current BIFV equipment configuration. Two of these performance areas were selected for additional development and test within the scope of the second year of the BIFV project. These are:

- Improved ammunition handling/storage equipment;

- Improved visibility from the troop compartment;

The work completed in each of these areas is reported in the subsections that follow. Other equipment areas for which training solutions were developed and tested are treated in Section 4.

Ammunition Handling/Storage Equipment And Procedures

Problem Definition

One essential element in the overall combat effectiveness of the Bradley Infantry Fighting Vehicle (BIFV) will be efficient employment of the 25mm gun. During typical engagements, ammunition for this weapon system will be expended at a high rate and reload will be a critical combat task. Reload of the 25mm gun must be performed in the minimum possible time because neither the 25mm gun, the coaxial machinegun, nor the TOW weapon systems can be employed while the turret is traversed to reload position. Therefore, any reduction in the average time required by crews to complete the reload procedure will impact significantly on the survivability of the individual vehicle and squad, and upon the contribution of that vehicle to successful completion of the unit mission.

Reloading ammunition for the 25mm gun is a complex task that requires troops to recall rules, perform mechanical operations, and work as a team. ARI/Litton researchers have observed performance of reloading in the institutional training environment. The general difficulty which troops have with critical parts of the procedure, resulted in excessively long completion times. This observation is confirmed by reports from the field. Times ranging up to 45 minutes have been reported and one informal report indicated that, in a competitive situation, the fastest squad required 25 minutes to reload while wearing winter gear and MOPP IV equipment.

Objectives

The overall objective of this research was to improve the configuration of the 25mm reload system. Four subgoals were formulated as follows:

- Simplify the system configuration to reduce the time requirements imposed by the system itself;
- Simplify the system configuration to permit the completion of the task by fewer individuals;
- Simplify the system configuration to reduce the training requirements;
- Modify the system configuration to increase the number of rounds carried by the vehicle.

The research project was initiated with these goals and with focus on the 25mm gun. During the course of the project, it became apparent that the secondary objective of improving the reload system for the coaxial machinegun could be accomplished within this project, as well. Details of the work for both weapon systems are presented in the following section.

Approach

The research team developed a thorough understanding of the details of the present reload system configuration, using the methods of study, observation and hands-on exercise of the system. The critical path traveled by a 25mm round, from a supply source to the gun, was analyzed and major points for constructive modification of the system to improve the man-system interface were identified. These are:

- The ready box
  (Current BIFV nomenclature designates the right side as the HE ready box and the left side as the AP ready box. However, the two types of ammunition are interchangeable as far as the reload system is concerned);

- Right-side storage containers--currently designated for HE ammunition;

- Deck-well storage containers--currently designated for AP ammunition;

- The ammunition shipping container (for either HE or AP).

The same approach was employed to identify constructive modifications to the reload system for the 7.62mm coaxial machinegun. The research team determined that the potential for improvement and simplification of the system was greatest at two points;

- The ready box frame;

- 7.62mm ammunition containers.

The remainder of this section presents an overview of the modifications identified above. Detailed drawings, specifications and new system procedures are presented in Annex 3.

Modification of the 25mm Ready Box. The modifications of the 25mm AP and HE ready boxes consist primarily of removing the loading rails and floor baffles (see Annex 3 for detailed drawings). The schematic, below, shows the current configuration with rounds looped vertically on the rails (see Figure 1-A), and the ARI/Litton modified ready box in which rounds can be laid in overlapping horizontal rows (see Figure 1-B).

"AP" Compartment "HE" Compartment

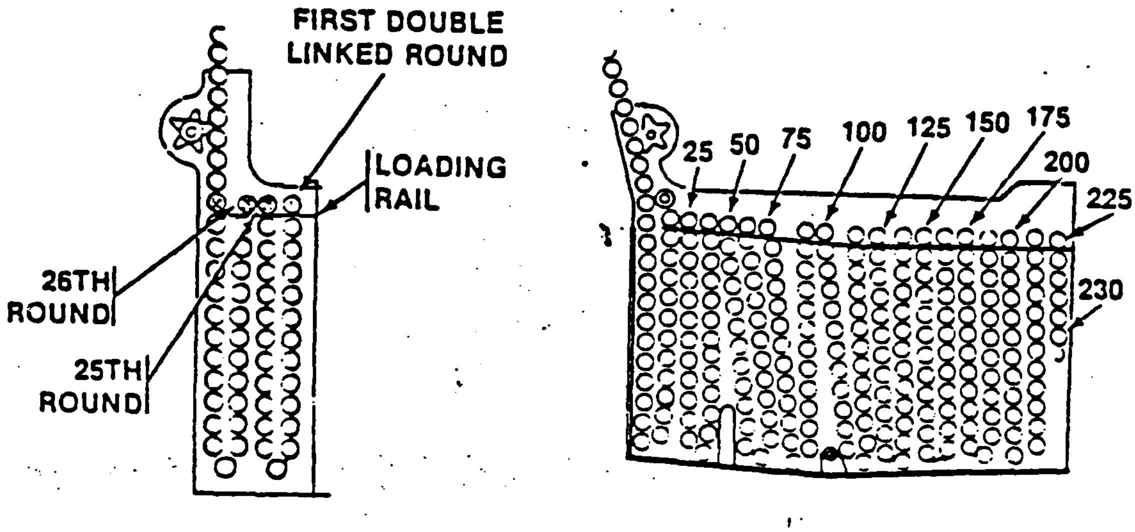


Figure 1-A. Schematic of the Conventional 25mm Ready Box.

"AP" Compartment "HE" Compartment

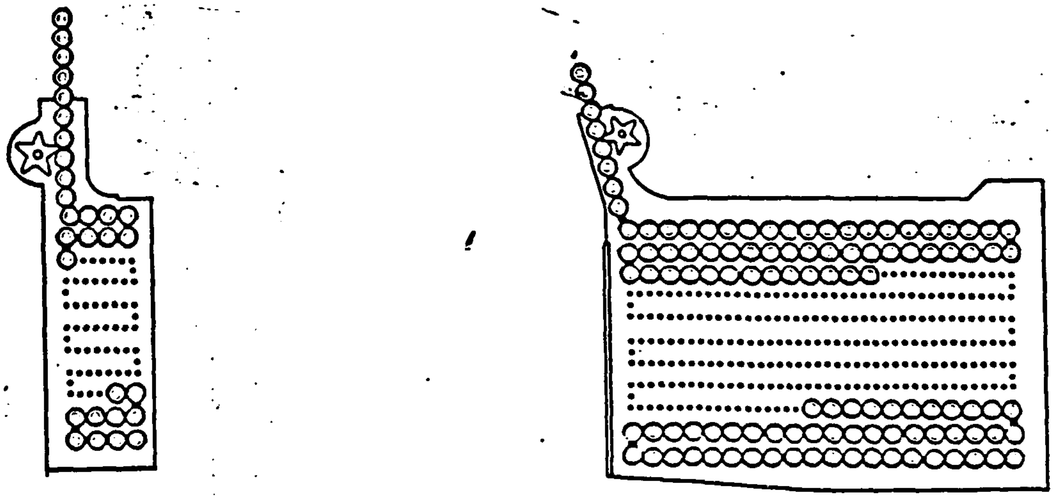


Figure 1-B. Schematic of the Modified Ready Box.

Figure 1. Modification of the 25mm ready box to permit horizontal layering of the rounds.

The modification eliminates the requirement to count rounds. This was a part of the reload task that was time-consuming and error-prone. Additionally, the modification increases the HE ready box load capacity from 230 to 314 rounds, and the AP ready box capacity from 70 to 96 rounds.

Modification of the Right-Side 25mm Storage Containers. In the present BIFV configuration, on-board ammunition storage utilizes a plastic ammunition shipping container that holds two 15-round belts (either HE or AP). The square black plastic ammunition storage containers are very awkward to use. The procedure requires that the soldier open the box, remove one belt (15 rounds), remove a plastic ammunition separator, replace the separator in the box, turn the box around, open the remaining side, and repeat the ammunition removal process.

In storage sites along the right side of the BIFV troop compartment, 180 rounds are presently stowed in 6 boxes. The modification replaces 4 of these boxes with 2 of the newly-designed containers, each holding a 150-round belt (Detailed drawings, specifications and instructions for this new container can be found elsewhere.) In the ARI/Litton modified configuration 360 rounds can be stowed in the space presently having a 180 round capacity.

In the present configuration, reloading requires that the two 15-round belts in each container be linked and then joined to belts from other containers. Each linkage requires that a round from one belt be removed, two adjacent belts be joined, and the round be reinserted to its former space. The newly-linked rounds must be inspected to insure that there are no misaligned rounds which could cause a misfeed at the gun. Thus, substituting a prelinked 150-round belt for the present 15-round belts represents a saving of 10 linkages, reducing both time requirements and chances for error. Additional features of the new container eliminate the plastic round separator, permit easier opening of the container at the hinged end, and allow accelerated removal of the rounds with direct feed from the container to the ready box. These modifications reduce time and errors, in that upload of 300 rounds from the two new containers to the HE ready box requires 20 fewer linkages and both the containers and rounds can be handled more efficiently within the crowded confines of the BIFV.

Modification of the Deck-Well 25mm Storage Containers. In the present configuration, seven plastic ammunition storage containers are stowed under the floor of the troop compartment. Reloading procedures utilizing the ammunition stowed in this location require removing the floor plates, extracting the separate containers from the well, and linking the 15-round belts in a crowded area. The modification substitutes a container which is designed to rest beneath the left and center sections of the deck-well. Each container has 76 rounds in two belts and is top-hinged at the forward end to permit removal of the rounds without extracting the container (the deck plate is also hinged to eliminate the need to completely lift the deck plate).

This modification reduces the number of required linkages, reduces the work space requirements when transfering rounds from container to ready box, and permits the reloading crew to work without removing items entirely from the deck.

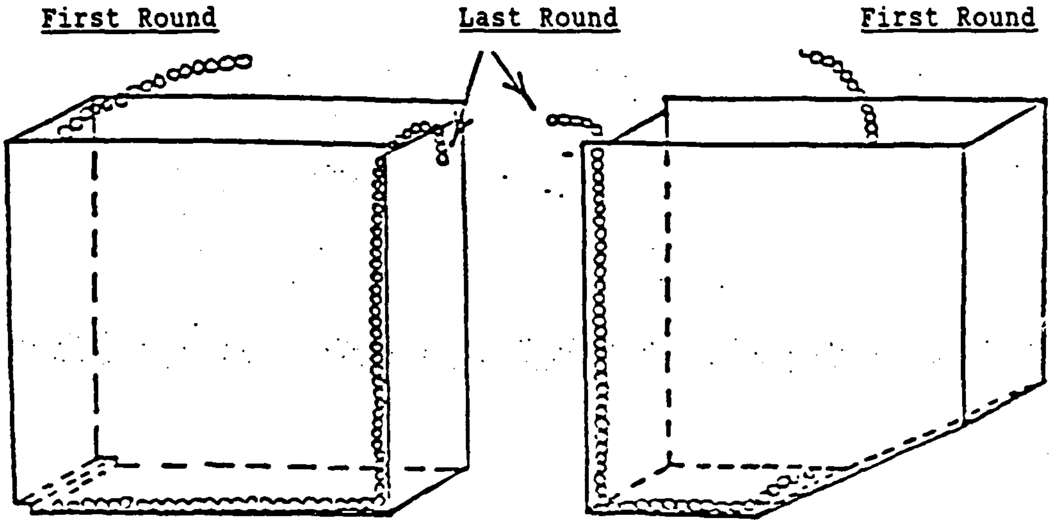
Modification of the 25mm Ammunition Shipping Container. As noted, the present square black plastic shipping container creates problems in the entire ammunition storage and handling system. A prototype box was developed for use as a possible substitute for the present box. This prototype is rectangular and holds one 25-round belt of prelinked ammunition (either AP or HE). To pull the entire belt directly from the box, one end is opened by releasing a simple latch; both ends are hinged so rotation of the box would never be necessary. This eliminates the multiple steps required by the present box. A further advantage of the newly-designed container is that it may be tilted or pulled slightly from its storage position on the shelf of the BIFV and then emptied, without entirely unstowing and finding a spot in the troop compartment to manipulate it.

Since the prototype box holds 25 rounds in one belt, the number of linkages required is reduced as the present box contained two 15-round belts which have to be linked immediately. Although at first inspection the smaller number may represent a loss, the space saving design of the new container is such that a greater number of these units can be stored in a smaller area, thereby actually increasing the total round stowage capacity. Additionally, the number 25 is a more "familiar" number for troops to work with, decreasing confusion about the number of boxes that must be opened during a given reload task. An example of the use of the new shipping container is that the reload crew can easily recall that filling one of the right-side 150-round stowage containers described above will require opening exactly 6 of the new shipping containers; this will consume less time than is required with 5 of the original boxes and the 6 new containers can be stowed along the left side of the vehicle in less space than is presently occupied by 5 of the present plastic containers.

Modification of 7.62 Coaxial Machine Gun Reload System. In the present configuration, the ready box is a curved framework with two interior baffles that is designed to hold 800 rounds of ammunition. The interior baffles create three compartments that must be filled separately. The present ready box is awkward to fill. The Bradley Commander must reach up and to his right to load these compartments by feel as the interior of the box cannot be seen. The 7.62mm ammunition is stored within the troop compartment in containers holding 200 rounds in two 100-round belts. This must be linked by one individual in the troop compartment and passed to the Bradley Commander for loading in the ready box. The complete process of reloading the coaxial machinegun requires a minimum of 8-10 minutes.

The modified coax ready box has straight sides and a simplified interior. Instead of the three-section box, the new ready box consists of an exterior framework. This is constructed to hold two new ammunition containers that are designed to be removable from the frame itself. Each container can be filled independently by personnel within the troop compartment. There is an additional paired can for each of the two in the ready box and these are storable (filled) on a shelf below the ready box. The new system creates a great deal of flexibility by maintaining at least 450 rounds at the ready at all times. When the first can is exhausted it can be removed and replaced by its paired can from the storage shelf while firing continues from the second container. The emptied container is immediately refilled from the conventional

on-board storage containers available in the troop compartment and is then placed on the shelf. The same procedure is replicated with the forward ammunition can when it is exhausted. Figure 2, below, shows the procedure for loading rounds in each of the new containers and the loading sequence as rounds are expended. The process of replacing the two cans and performing the one linkage required to join the 450 round belts can be performed in less than 30 seconds.



Loading Sequence

	Action Required	
Condition	Forward Can	Rear Can
1. Initial Loading	1. Put in new can 2. Link first round to last round of rear can	1. Put in new can. 2. Place first round in in feed chute.
2. Rear can empty-Forward can full		1. Remove old can. 2. Put in new (full) can. 3. Link first round to last round of forward can.
3. Forward can empty-rear can full	1. Remove old can. 2. Put in new (full) can 3. Link first round to last round of rear can	
4. Both cans empty	Same Action as 1.	Same Action as 1.

Notes: A. First round ALWAYS is single link. Last round is ALWAYS a double link.
B. Empty cans should go to Troop Compartment for refill ASAP.
C. ALWAYS strive for 2 full cans on shelf below ready box.

Figure 2. Coax machinegun reload procedures.

Evaluation Of The Modifications To The BIFV Reload Systems: 25mm Main Gun And 7.62mm Coaxial Machinegun

Several approaches were used to evaluate the modifications. A comparison test was considered appropriate for the 25mm reload system because of its complexity. The relative simplicity of the coaxial machinegun reload system permitted comparison to the conventional system on an informal basis. In addition to comparisons between old and new systems, live fire tests of both systems were conducted. The procedures for these evaluations are outlined in this section.

The purpose of the 25mm comparison test was to estimate the benefits which would be obtained by substitution of the modified ready box and ammunition containers (described above) for the conventional reload system configuration. For this purpose, a BIFV was equipped to serve as the test vehicle, with the modified reload system installed and all additional TO&E equipment stowed (to create the same crowded interior as would be present in a combat situation). A second BIFV, with the conventional reload system and fully combat-loaded, served as the control vehicle for comparison testing.

The eight BIFV squads participating in the evaluation were supplied by 29th Infantry Regiment at Fort Benning. All squad members were BIFV experienced. Each squad was given an untimed and supervised refresher trial with the conventional system (with research personnel correcting errors and omissions), to ensure that all squads were proficient at performance of the conventional procedures. The squads performed the refresher trial, and all subsequent evaluation trials, wearing load bearing equipment (LBE), and MOPP IV equipment except for protective mask. After the initial refresher trial, all evaluation trials were performed with the ramp closed as it would be in the combat situation.

Time required to complete the reload task formed the baseline for comparison purposes. During this evaluation, the reload task was defined as the loading of the standard 230 rounds of ammunition to HE side of the ready box and 70 rounds to the AP side. Plastic practice ammunition was used for all trials.

Elapsed time was recorded by standard stopwatch. Each trial began with the turret positioned at 6400 mils and timing began with the signal to start. The gunner traversed the turret first to the HE reload position (2150 mils) and the squad began the reload task. The intermediate time was recorded when the squad announced to the gunner that the HE side of the ready box had been uploaded. The gunner then traversed the turret to the AP load position (4350 mils) and timing continued until the AP upload was completed. Performance measures thus consisted of HE Load Time, AP Load Time, and Total Load Time.

Each squad performed the reloading task 4 times, under varying combinations of the conventional and modified reload configurations. Half of the squads began with the existing ready box and the conventional plastic ammunition containers (this condition will be referred to hereafter as the OLD-OLD condition). This condition was followed by performance of the reload task using the modified ready box and ammunition containers (hereafter referred to as the NEW-NEW condition). The conditions were reversed for the remaining

squads, beginning with reloading in the NEW-NEW condition and followed by complete performance of the task in the OLD-OLD condition. This counterbalanced sequence of task performance permits comparison of the total reload times for the old and new system configurations.

Following the two initial trials, each squad performed the reloading task once with the new ready box and the old containers (NEW-OLD condition) and once with the old ready box and new containers (OLD-NEW condition). Data from these conditions permitted estimation of the separate effects of modifying the ready box alone or modifying only the ammunition containers.

Finally, as a pilot test to obtain an estimate of the minimum average time required to reload using the NEW-NEW system after extensive practice, four squads performed additional iterations of the reload procedure using the new ready box and new ammunition containers. The squads were instructed to perform as quickly as possible and the squads indicated that they felt they were in competition with each other.

Following the completion of the comparison test, live fire demonstrations were conducted for both the main gun and machinegun systems. The weapon systems were exercised under stressful conditions to determine if problems attributable to the modified reload configuration would appear. Procedures for conducting these tests can be found in Rollier, et al., 1987.

Evaluation Results

The evaluation procedures described above permit the use of Analysis of Variance techniques for analysis of the task data. Detailed statistical results are presented separately; significant results are summarized here. Table 1 shows the mean total reload times obtained for the conventional system (OLD-OLD), the modified system (NEW-NEW), and for hybrid systems where either the ready box or ammunition cans were modified separately (NEW-OLD and OLD-NEW).

Table 1

Comparison of Mean Total Reload Times

Condition	Mean Time	% Reduction
OLD-OLD	12' 51"	
NEW-NEW	7' 21"	43%
NEW-OLD	10' 33"	18%
OLD-NEW	7' 17"	43%

The combination of modified ready box and modified shelf and deck-well containers clearly results in reduced time to load, compared to the present system configuration. The overall effect is contributed to about equally for

each of the two types of ammunition (HE alone shows a 46% reduction in time; AP alone shows a 38% reduction in time).

The overall reduction in total reload time of 43% using the new system would appear to be a conservative estimate of the advantage of the modified ready box and new ammunition containers. The four squads which were given additional practice with the new system (two added trials for 3 squads; three added trials for the fourth squad) achieved a "best estimate" reload time of 2' 22." This represents an 82% reduction over the average time of 12' 51" required for the old system by squads which had received prior training and experience with the old system, and, also, an untimed practice trial/coaching prior to the start of the experimental procedure. The statistical trend suggests that squads trained to maximum proficiency with both systems will perform the reload task in dramatically less time for the new system compared to the old.

Finally, the data show a more dramatic effect for modifying the ammunition cans alone (OLD-NEW, 43%), than for change in the ready box alone (NEW-OLD, 18%). However, the limitation in number of squads and vehicles available prevented employment of a rigorous experimental design capable of defining the partial effects contributed by the two separate types of system modification. Thus, the data do not unequivocably establish that greater gains were achieved by modification of the ammunition containers than by modification of the ready box. The appropriate conclusion would appear to be that both modifications should be implemented to ensure maximum reductions in reload time.

Discussion

The first objective of this research was to simplify the system configuration to reduce the time requirements imposed by the system itself. The evaluation results indicate that comparison of the modified system to the presently configured system produces a time reduction that is statistically significant and, more importantly, militarily significant when the combat criterion is applied. Although the exact times derived in the testing environment may not translate precisely to the combat situation, the apparent time reductions (in the range of 82%, or 5 to 10 minutes) could be critical to the survival of any one squad or to the successful completion of the mission.

Secondly, observation of squad interactions when employing the new system indicate that fewer individuals are required to complete the task in the reduced time. When using the old system, all soldiers present should be employed simultaneously in some aspect of the task; i.e., linking ammo, inspecting rounds, or helping to unload the boxes. The time required with the old system would increase if less than a full squad is available to perform the task. Conversely, with the new system, the task could be accomplished with no increase in time by the gunner and driver, if the dismount element is occupied away from the vehicle.

The objective of simplifying the system to reduce training requirements was accomplished, also. With the new system, an individual could, with verbal instruction from the gunner or commander, master the reload task quickly. The test was specifically designed to test the NEW-NEW system without benefit of

even minimal practice. Squads were merely shown, and did not rehearse, the task using the new system. In contrast, the conventional system is so complicated that even trained personnel have to refresh their memories by continually referring to the picture and instructions posted on the ready box door in order to prevent mistakes. In a combat situation where pressure is at a maximum and the potential for loss of one or more crewmembers is high, the option of assigning an untrained member to the reload task becomes very important. Additionally, the pilot test of practice effects with the new system suggest that the simplicity of the system will contribute to a very short learning curve. Squads improve dramatically in the first 2-3 training runs and should be able to achieve (and sustain) reload times in the 1-3 minute range with minimal institutional and unit training.

Finally, the space saving features of the new ready box and ammunition container designs result in an increase of approximately 200 rounds available in each vehicle, compared to the total capacity of the present system. The new ammunition container system provides an additional 100 rounds in on-board storage. An additional 100-plus rounds can be placed in the HE and AP ready boxes with each upload. Thus, the objectives of reducing the reload time constraints that are imposed by the system itself, reducing manpower requirements for the task, and simplifying the training requirements, can be achieved with the added bonus of increasing the number of 25mm rounds available to the gunner and commander during a combat mission. This will increase the tactical options available when, for example, determining the appropriate mix of HE and AP ammunition to be combat loaded or when and where to engage targets.

As indicated earlier, it was not considered necessary to conduct a duplicate comparison test in the case of the 7.62mm coaxial machinegun. However, a great deal of experience with the modified system was attained during the fabrication and installation of the modified ready box frame and ammunition containers. The system was exercised by subject matter experts and received favorable comments from these sources. It appears highly probable that the same four goals (as discussed in connection with the 25mm system) are attainable with the modified coax reload system.

These conclusions are supported by the results of the preliminary live fire demonstrations conducted at Fort Bennning. No misfeeds or other malfunctions attributable to the modified reload systems occurred. The new 25mm and coax systems were equally reliable.

Recommendations

The modified ready boxes and new ammunition containers have demonstrated potential for greatly increasing BIFV operational effectiveness. The modified reload systems for both weapons should be subjected to a full Operational Test conducted by an independent agency. This step should be given highest priority in order that BIFVs can be modified and the new procedures and equipment be made available to BIFV units without delay.

The process of independent validation recommended above, is underway. The concepts and evaluation results were briefed to TRADOC by ARI/Litton and to the Army Chief of Staff by TSM. As a result, the requirement for a concept

feasiblity test went forward to FMC Corporation. During the 12-26 September, 1985, time frame, operational tests were conducted by FMC Corporation at Camp Roberts as directed by Project Manager, Light Combat Vehicle (LCV). These tests were limited to investigating the reliability and suitablity of the modified ready boxes. An official report of the results is not yet available.

However, a member of the BIFV research staff participated in the conduct of the tests. In the opinion of this expert, the results unequivocably demonstrated the feasibility of the proposed modifications. The modified 25mm ready box performed suitably in all conditions except for the 60 percent, nose-down attitude. In this single case, ammunition within the ready box shifted and feeder problems resulted. Because the test managers judged the modified system to be superior to all other options previously tested, FMC requested approval add a baffle to correct the problem encountered in the nose-down attitude. Approval has been received through Project Manager, LCV, and re-testing was completed during October, 1985. Reports from FMC indicate complete success with the re-test.

During tests of the modified coax ready box, conducted by FMC at the same time, the single malfunction that occurred was attributable to the test weapon and not the reload system. FMC has recommended adoption of the new 7.62 reload system as designed by ARI/Litton.

The several new stowage containers developed by ARI/Litton were originally scheduled to be evaluated, also, during the recent test. This objective was deleted from the operational test because projected Block 2 modifications will address the issue of BIFV troop compartment storage (to include the ARI/Litton concept for storage containers) for all types of ammunition carried in the combat-loaded vehicle.

No direct test has been made of the ARI/Litton shipping container design. The prototype has been demonstrated and the concept has been briefed to interested agencies; to include representatives of the Army Ammunition Command, the PMO-BIFV, Office of Munitions Systems Manager (TRADOC) at Redstone Arsenal, and the USAIS Combat Developments Directorate. Each of these agencies expressed interest in and support of this new shipping container concept.

In conclusion, the utility and feasiblity of the ARI/Litton modifications to the 25mm and 7.62mm reload systems have been supported from several independent sources. Final determination should be expedited in order to make the thoroughly validated modifications available to BIFV units as soon as possible. Specifically, it is recommended that:

- The modified 25mm and 7.62mm ready boxes be adopted;
- The modified on-board 25mm storage containers be adopted;
- The modified 25mm shipping containers be adopted.

Troop Compartment Visibility

Problem Definition

One aspect of the problem analysis conducted during the initial phase of this project was to contrast the characteristics of the Bradley with the M113 which it replaces. The Bradley represents a vast technological advance over the previous armored personnel carrier, and this gives the Army greater capability to perform many conventional mechanized infantry tasks better and to utilize this sophisticated weapon system in many new ways. However, the research team noted very early in the project that the advanced design of the BIFV actually created some issues that were not an area of concern with the M113. Three of these issues relate to the difference between the completely open hatch design of the M113 and the enclosed troop compartment of the BIFV. These issues are: (a) local security; (b) passive air defense; and, (c) motion sickness and claustrophobia. Therefore, an improved system of providing a view of the battlefield from within the troop compartment was selected as an area for investigation during the second year of the project, because one solution could potentially address multiple issues.

The deficiencies in the degree of visibility possible from the troop compartment were reported in the documentation of the problem analysis phase (see Bibliography). Additional impetus to selection of this area for further work during the second year of the project was provided by a request from the Director of the Department of Training and Doctrine, and the Combined Arms and Tactics Department of the U.S. Army Infantry School, that ARI/Litton investigate alternative approaches to improving troop compartment visibility. The completed work and directions for further development are described in this subsection. Additional background defining the problem is given first.

Visibility to Flanks and Rear

Personnel in the troop compartment must perform a number of tasks which are dependent upon the ability to see the battlefield. These are:

- Operation of the M231 Firing Port Weapon mounted in conjuction with a vision block;
- Detection of threat dismounted infantry and mechanized targets at a distance;
- Maintaining close-in local security during halts;
- Reconnaissance of the battlefield prior to dismount.

A vision block system provides the only mode of viewing outside the vehicle when the troop compartment hatch is closed. Normal performance of the tasks listed above is highly dependent upon the degree of visibility the soldier can obtain through one of the vision blocks. In its present configuration, the troop compartment of the Bradley has seven periscopes (vision blocks) mounted two each on the right and left side of the vehicle and three on the top of the

hull facing to the rear. Each vision block is a double prism that is eleven inches in height and eight inches wide. A fifteen degree upward tilt of the prism allows greater long distance viewing.

During the unit exercises observed by the research team, the periscopes required frequent cleaning to remove dust, mud or snow and this can only be done by an individual from an exposed position outside the vehicle. Further investigation by the team produced a plot of the dead space resulting from inadequate overlap of the field of view from adjacent vision blocks (see Figure 3).

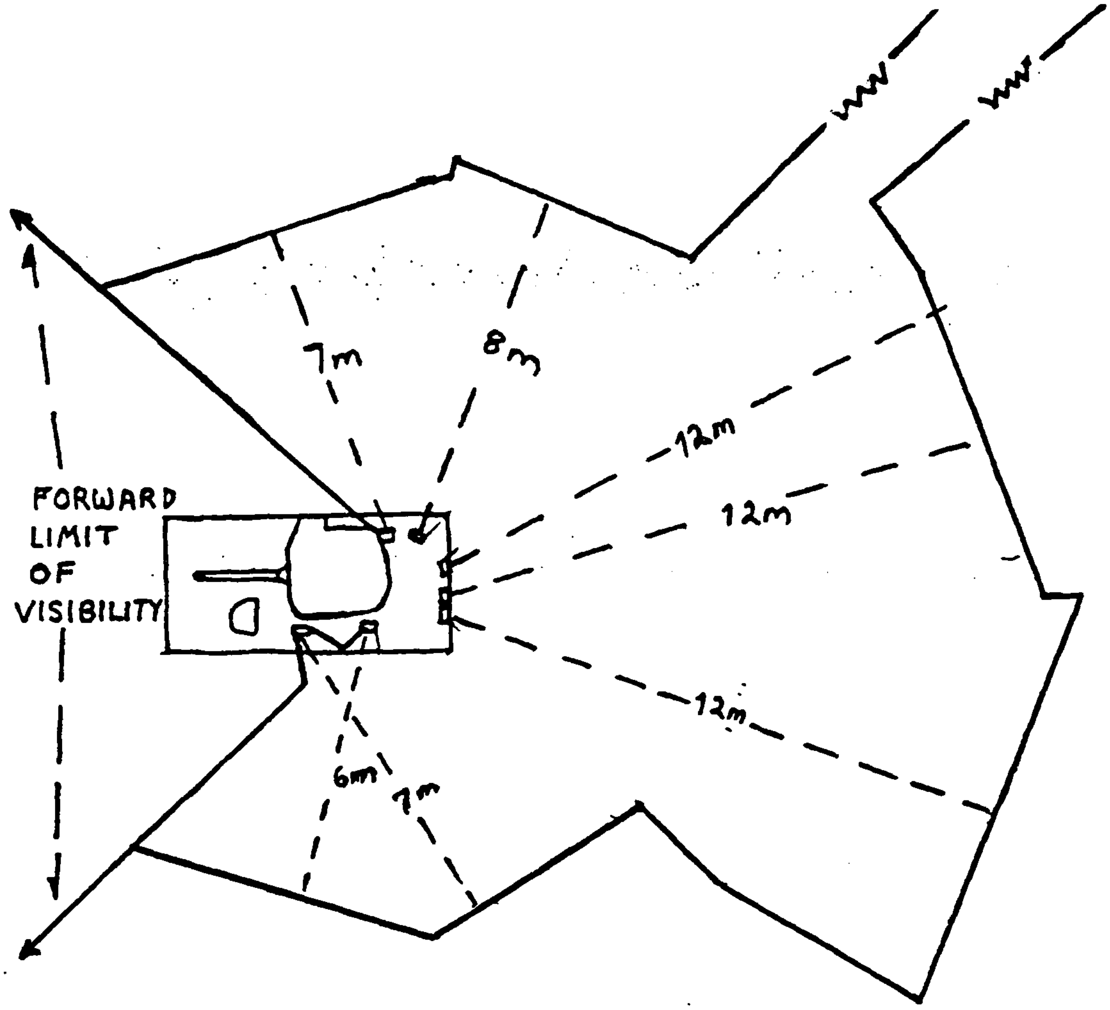


Figure 3. Approximate dimensions of BIFV ground level deadspace.

This dead space envelope was determined by moving an object out from the vehicle until it could be detected at ground level from a vision block. This exploratory test was done under daylight conditions. The figure shows that the detection distance under these conditions is 6-8 meters on the flanks of the vehicle and 10-12 meters to the rear. Additional data collection would be necessary to determine the capabilities for detection of objects at varying

heights above the ground under all visibility conditions, with and without vision enhancement devices. However, many tactical situations in urbanized or heavily vegetated environments could be envisioned in which the dead space shown above could have disastrous consequences.

In short, the vision block system suffers from serious lack of close-in visibility at all times, and vision at a distance can become blinded at critical times by obscurants.

Overhead/Panoramic Visibility

As noted, there are additional tasks requiring a reliable means for obtaining a view of the battlefield. These are:

- Performance of Fire Support Team (FIST) and Forward Observer (FO) tasks;
- Performance of airguard tasks.

The ability to perform these functions using the current vision block system is totally limited, and current doctrine prohibits the option of placing an individual in the cargo hatch opening to perform these tasks. The turret override must be engaged for the turret to function with the hatch open and this poses a safety hazard to the individual in the hatch and the other personnel in the troop compartment. The speed and mobility of the Bradley make it difficult to maintain balance while standing in the hatch. Finally, an open hatch increases the threat to troop compartment personnel from artillery fires. At present, the commander and gunner hatches are the only positions from which these tasks could be performed. However, the primary responsibilities of these individuals preclude effective performance of FO or airguard tasks as addititional duties. The research team observed that current practice in units is to ignore passive air defense except to the degree that the Bradley commander can observe the air as part of his duties. Secondly, the FO typically rides in the troop compartment of the platoon leader's vehicle and can perform in the intended role only when it is possible for him to dismount.

Morale of Troop Compartment Personnel

In addition to noting the need for an improved visibility system in order to perform combat tasks from the interior of the troop compartment, research team observers noted a tendency on the part of troop compartment personnel to develop motion sickness and feelings akin to claustrophobia after periods of confinement in the crowded interior. The closed-in feeling is somewhat alleviated when the cargo hatch is open, but current doctrine and combat conditions will normally dictate that the hatch remain closed. A vehicle modification that provides a wider field of view without impacting on personnel safety would give the soldier a greater feeling that he is able to stay current on what is going on outside the vehicle. This should benefit both morale and the performance of tasks from within the troop compartment.

Approach

The research team identified candidate technologies showing potential for improving visibility from the troop compartment. Three candidates were pursued in some depth: (a) redesign or rearrangment of the present vision block configuration; (b) fiber optics relay of the ISU sight picture to the troop compartment; and, (c) development of a transparent cargo hatch cover. For each candidate, the feasibility of producing and implementing a modification of the vehicle was assessed, and the potential of each candidate modification for solving the present problems with troop compartment visibility was analyzed.

The Present Vision Block System. Manufacturers of periscope/vision block products were contacted to determine the state-of-the-art in this technological area. Present product development efforts, which could impact on the current BIFV vision block system, involve changes which increase the field of view from any one vision block and changes in mounting locations and angles to improve overlap from adjacent periscopes. Additionally, planned modifications to the M3 (the Cavalry Fighting Vehicle) involve adding vision blocks mounted in the cargo hatch cover. After determining that other agencies were pursuing approaches to improved troop compartment visibility that concentrate on modifications of the present vision block capabilities, the research team estimated the degree to which these modifications would address the problems noted in the field. The projected improvements could increase effective employment of the firing port weapon and detection of local threat to the flanks and rear of the vehicle. However, performance of FIST/FO functions, detection of the enemy air threat, and the potential for one individual (e.g., the assistant squad leader) to obtain a panoramic view of the battlefield prior to dismount, would benefit little from changes limited to the present vision block system.

Fiber Optics. Fiber optic technology offers the possibility of transmitting the ISU sight picture to a TV monitor mounted in the troop compartment. However, the ISU and turret would require modifications of significant cost to implement the technology. Additional research would be required to determine the reliability of such a system under high mobility conditions. Resolution of the monitor image to produce an interpretable picture would also require research. A means for rapid determination of the turret orientation at any given time would have to be added. After determination of the high potential cost of a fiber optic system and identification of the needs for additional research before the advantages of such a system could be established, the research team concluded that other approaches should be pursued first.

Transparent Cargo Hatch Cover. This approach was selected for further work during the second year of the project. The concept for a see-through capability, with the cargo hatch closed, specified the following requirements:

- An individual must be able to make a panoramic lateral scan of the battlefield (approximately 270 degrees, exclusive of the area to the front obscured by the turret) without moving from his position in the troop compartment;

- An individual must have an unobstructed overhead view from horizon to vertical;

- The dead-space envelope must be reduced to give greater visibility close-in to the vehicle;

- The ballistic protection provided for troops must be equal to or greater than that afforded by the present aluminum cargo hatch cover;

- The design must permit replacement of current cargo hatch cover without requiring hull modification or interfering with 25mm gun barrel travel;

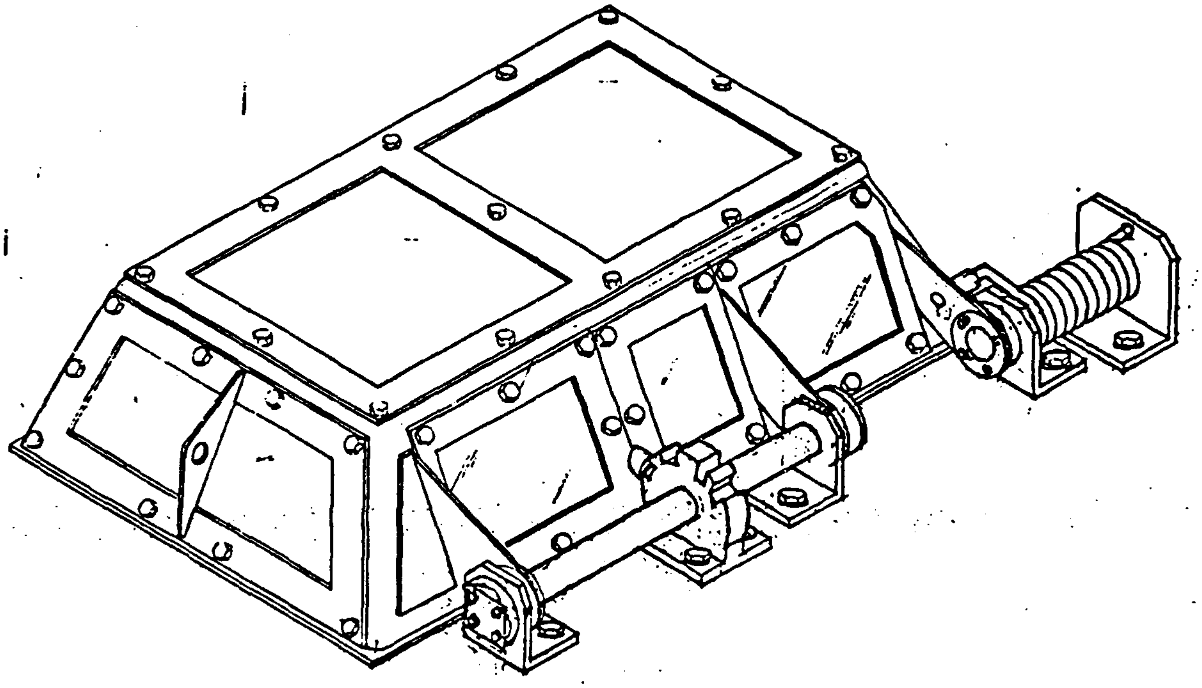
- The transparent viewing surface must not distort unaided vision and vision aided by magnification devices or STANO (Surveillande, Target Acquisition and Night Observation) devices, to any significant degree.

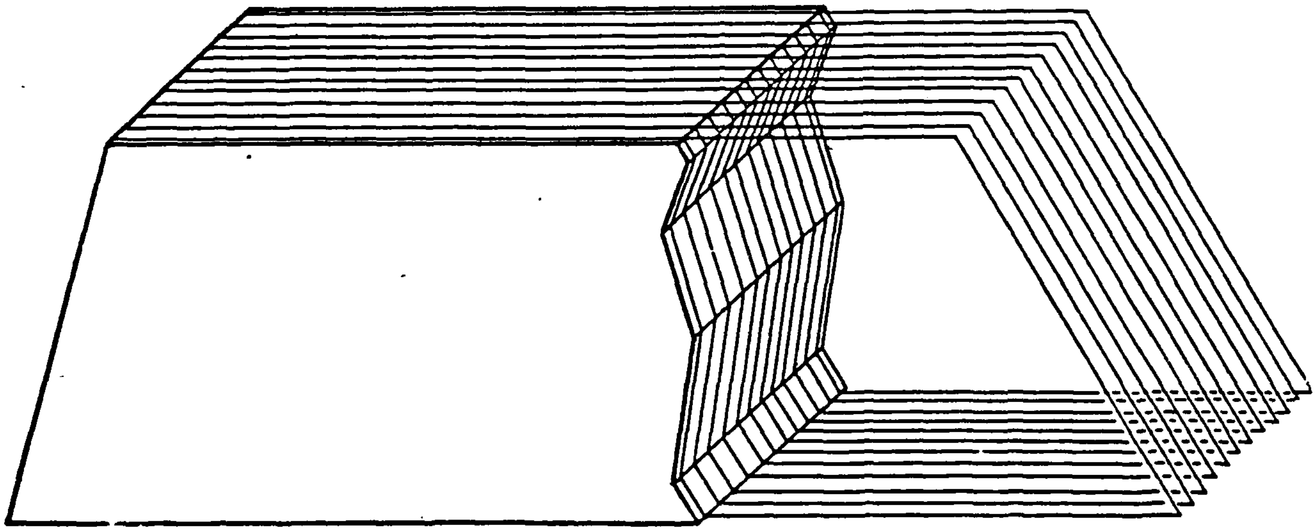
With these requirements in mind, the research team proceeded with the design of a prototype. Manufacturers of bullet-proof glass were canvassed to determine the feasibility and estimated cost of transparent viewing surfaces that would meet the specified needs. Representatives of the firm, Vision Blocks, Inc., demonstrated a product consisting of 12 bonded layers of glass totalling three inches in thickness. The interior surface is laminated to prevent spalling. Distortion of visibility through the glass is less than one percent and the reflectivity of the glass surface can be reduced by 65% with the use of an emulsion spray. The weight of this product is 30 pounds per square foot.

A contract was initiated with Vision Blocks, Inc. to produce a prototype that utilized this glass product mounted in a frame meeting the specifications of the present cargo hatch cover. Manufacturers having the capability to produce such a frame were canvassed and Engineered Systems Co. was selected to fabricate the mounting for the glass surfaces. The basic shape selected was a domed frame with trapezoidal viewing surfaces. Figure 4 shows a schematic of the transparent cargo hatch cover as designed by ARI/Litton and fabricated by the contractor.

The entire assembly is 48 inches long by 30 inches wide at the base, with a center height of 12 inches above the plane of the hull. The frame is constructed of light carbon steel bolted in an arrangement which permits disassembly for replacement of individual glass surfaces as necessary. The mechanism for opening the hatch cover is a modification of the present torsion bar arrangement to accommodate the increase in weight (600 lbs versus 350 lbs) required by the added volume of frame and glass.

The prototype was delivered to ARI/Litton in October, 1985. An immediate opportunity to conduct limited evaluation of the prototype arose when it was found possible to satellite the testing to a field exercise scheduled during November, 1985. The procedures and results are described below.





Cross Section of Laminated Glass

Figure 4. Details of the transparent cargo hatch cover.

Evaluation of the Prototype Transparent Cargo Hatch Cover

Procedure. As noted in Section 1 of this report, the ARI/Litton research team conducted a study of BIFV leader span of control using a three-day tactical exercise as a setting. It was determined that the prototype could be subjected to trial within this setting also, with the scope of the evaluation limited to data collection that could be accomplished without interfering with the tactical focus of the study.

Permission was obtained to mount the prototype cargo hatch cover on one of the vehicles supplied for the tactical test by 1st Battalion, 29th Infantry. The BIFV assigned to the friendly force platoon leader was selected. During the exercise, the troop compartment of this vehicle carried an individual assigned to FO duties, the platoon leader's RTO, the medic, and the ARI/Litton team member performing the observer role. An observer checklist was constructed prior to the exercise that called for notation of items such as the amount and type of use, maintenance required, observed instances where the prototype transparent cover contributed to effective performance of combat tasks, and anecdotal evidence relating to user attitudes toward the modification. A post-exercise questionnaire was completed by the troop compartment personnel to elicit further reactions on the advantages/disadvantages of the transparent cover.

In summary, the evaluation procedures permitted exploratory analysis of the degree to which the prototype impacted on troop compartment visiblity issues. The evaluation opportunities included a variety of tactical situations, variations in weather, alternating static and high speed maneuver conditions, and both daylight and limited visiblity situations. Data was accumulated from both a trained observer and active duty personnel.

Observations. Though the trial procedures were frankly exploratory and not designed to produce the volume of systematic data required to completely validate the concept of a transparent cargo hatch cover, useful observations on the performance of the prototype were obtained. Results bearing on the feasiblity of the concept are:

- FO tasks were performed effectively from within the troop compartment by an experienced mortar platoon member attached to the platoon command vehicle--comments from this individual on the advantages of the cover were positive;

- Personnel in the troop compartment spontaneously commented on the increased capability for early detection of enemy air threat afforded by the new cargo hatch cover;

- Close-in dead space was reduced to within three meters (approximately), with the vehicle on level terrain;

- Inclement weather during the exercise resulted in obscured vision from the periscopes but vision from the transparent cargo hatch cover was never degraded by mud, condensation or other obscurants;

- Comments from troop compartment personnel reflected the perception that the cover reduced feelings of claustrophobia and motion sickness.

- Troop compartment personnel categorically preferred the new transparent cover to the original cargo hatch cover. However, users expressed some concerns about the concept that reinforced the awareness of the research team of the need for the following actions to further develop the concept and expedite implementation:

  (1) Design of a seat with height adjustments to provide support and eliminate cramping resulting from inability to stand fully upright when viewing through the cover;

  (2) Addition of interior opaque covers with Velcro fasteners to support proper light discipline;

  (3) An information program that assures troops that the modification provides ballistic protection equal to or greater than the present metal cover;

  (4) An information program that assures troops that light reflection from the cover is manageable and will not increase the ability of the enemy to detect the BIFV.

In summary, the prototype was subjected to trial during a tactical exercise conducted in November, 1985. The results support the following conclusions: (a) effective performance of combat tasks from the troop compartment is facilitated by the transparent hatch cover; (b) troop compartment personnel react positively to replacement of the present cover with the modified cover; (c) the general feasibility of the concept is supported by the fact that all noted problems with the prototype are susceptible to solution within minimal time and cost parameters.

Recommendations

The limited feasibility trial demonstrated that the prototype transparent cargo hatch cover is a viable concept. The research team formulated recommendations for further work to refine the concept. Specifically, it is recommended that:

- The transparent cargo hatch cover be subjected to complete operational test;

- A two-man bench seat with height adjustment be designed for use with the cover;

- An interior cover to provide proper light discipline be perfected;

- Research and development to reduce light reflection to minimal levels be performed;

- Systematic studies be conducted to compare advantages/disadvantages of the modified cover to the present cargo hatch cover in the areas of;

  (1) Performance of passive airguard tasks,

  (2) Performance of FO tasks,

  (3) Performance of local security tasks,

  (4) Reduction of incidence of claustrophobic reactions,

  (5) Reduction of incidence of motion sickness,

- Systematic studies be conducted to determine the degree of user acceptance of the transparent cover.

BIFV TRAINING

Overview

This section describes second year work in a number of discrete areas. The areas are related in that each approaches a solution to identified problems through improvement in current BIFV training. The following areas were selected by the ARI/Litton BIFV Research Team as having high payoff potential within the scope of the second year work program:

- The Thermal Mode of the ISU;
- The BIFV Commanders Course;
- Night/Limited Visibility Conditions;
- Through-the-Sight Video;
- Scale Vehicles and Scale Ranges.

Substantial problems with effective employment of the thermal mode of the ISU were noted by the research team during the problem analysis phase. It was determined that, in this case, development of improved procedures for use of the equipment and improved training for users, was a more appropriate approach to a solution than attempting to modify the equipment itself. For the next area listed above, review of the BIFV Commanders Course resulted in recommendations for revising/augmenting the present program that prepares individuals to command the vehicle and/or BIFV Units. Presently existing voids in BIFV training were addressed in the area of unit training for night operations. The final two areas, through-the-sight video and scale vehicles/ranges, explore the development of needed training tools for increasing realism and training effectiveness over a broad spectrum of BIFV combat tasks.

The completed work in each of these areas is summarized in a following subsection. Additional details, exhibits and written products are presented in associated annexes, as appropriate.

Thermal Mode of the Bradley Integrated Sight Unit

Problem Definition

In future conflicts, effective employment of the BIFV during periods of limited visibility (at night and when the daytime battlefield is masked by weather or obscurants) will be critical to mission success. The thermal mode of the BIFV integrated sight unit (ISU) was designed to play a significant role during limited visibility periods. The performance of the BIFV commander and gunner in their surveillance of the battlefield and utilization of the BIFV weapons will be significantly degraded if this equipment fails or is ineffectively employed.

Field observations conducted during the problem analysis phase isolated the fact that the thermal mode of the ISU does not fulfill its intended role at present. Users indicated to research team members that the thermal sight could not be employed in the manner intended, except at very short ranges.

Additional problem analysis was performed by the ARI/Litton research team to determine the source and validity of the user perceptions. One pervasive problem became apparent when different SMEs described the capabilities of the ISU in the thermal mode. This is the fact that the four terms of detection, classification, recognition and identification are employed ambiguously by users. These terms are frequently used interchangeably, or one catch-all term is used without appreciation of the differences in meaning between the four processes.

For several years, a research program being conducted by ARI-Fort Hood Field Unit titled The Target Acquisition and Analysis Training System (TAATS), has focused on some of the problems involved in target detection and related issues. The TAATS program has utilized four terms for separate aspects of the stepwise process of target acquisition. Definitions for these terms are modifications of those used by the TRADOC Combined Arms Center:

- Detection--discovery of a potential target by whatever means available; awareness and reporting that there is an object of interest in the field of view that should be further analyzed;
- Classification--gross differentiation of targets according to class; e.g., tanks, trucks, personnel, wheeled vs track;
- Recognition--determining, within a class, whether an object is friend or threat;
- Identification--determination, within a class of friend or threat, of specific identity by name or number; e.g., Abrams Tank, M60 tank, T62 tank.

It is important to maintain these distinctions, particularly between detection and identification, when discussing the capabilities and limitations of the ISU as a tool in these processes. Also the training of users to optimize the inherent capabilities of the equipment should establish this vocabulary and

include training in each process. At present, when an individual indicates that the thermal mode of the ISU cannot be used effectively for target detection, he may in fact mean that objects can be discovered but not identified or named, given the thermal image that has been detected within the sight picture.

The general literature review that was conducted during the problem analysis phase provided the research team with further basic information applying to the BIFV ISU (thermal mode). This literature falls into three major areas;

- The physical principles of thermal radiation and the devices available for producing visible thermal signatures;
- Human factors research related to performance of friendly force identification and gunnery skills under high visibility conditions, using either aided or unaided optical techniques;
- Basic literature and military documents (e.g., manuals, training texts and lessons learned), related specifically to performance of tasks using thermal devices.

The literature is relatively rich in the first two areas and provides the necessary background for focusing on the area of thermal imagery. In the latter case, the work produced by two agencies, the TAATS group at ARI-Fort Hood and the Night Vision and Electro-Optical Laboratory at Fort Belvoir, proved the most useful for the BIFV research team. The literature review is treated in Rollier, 1985. The overriding conclusion drawn by the research team is that, with the best of equipment, the use of a thermal sight is a complex task. It is noted in Army ST 17-199, Mounted Night Operations, (1983):

> "To the untrained eye, they (thermal images) may appear to be only glowing spots on a dark background. To a trained operator they may become distintive targets, characterized by specific shape and outlines with glow points or hot spots at certain places within the outline. Thermal sights challenge their operators to interpret and understand the unusual images that are generated." (ST 17-199, pp 01-02)

If the complexity of the task is accepted as a given, the operable words in the quote are training and challenge. In order to assess, further, users' perception that the task is impossible with the BIFV thermal sight, the research team next utilized the information obtained during the overall review of BIFV-related resident instruction, NETT training or unit training. It was determined that guidelines for manipulation of the ISU thermal controls are not provided in current BIFV instructional programs, primarily because knowledge as to how best to utilize the ISU in the thermal mode is not widespread within the BIFV community. For example, gunners are told that the thermal ISU controls should be adjusted like those on a television set, moving the focus, contrast and brightness dials until the image looks "good." No further hints are given, nor is it suggested that the controls should be changed frequently to reflect changes in target type, viewing distances, or ambient temperatures. Additionally, no study aids are available for ISU users to practice with

thermal cues, or even to gain experience in seeing what an actual vehicle looks like through the thermal sight. On the tactical level, techniques have not been defined for the conduct of sector searches or range scanning in the thermal mode. There is little information available concerning the problems associated with extended use of the thermal viewer and optimal time periods for thermal sight use. In short, there are few guidelines or training materials for use of the BIFV ISU in the thermal mode.

Objectives

The thermal mode of the ISU was identified during the problem analysis phase as a candidate for further work during the development and evaluation phase. Because this equipment will be critical for effective employment of the BIFV and its weapons during limited visibility operations, research to improve the performance of users will have high payoff. The specific objectives pursued during the second year of the project were as follows:

- Develop guidelines for resolution of the ISU thermal image;
- Develop techniques for scanning the battlefield and determining ranges through the ISU (thermal mode);
- Develop lesson plans and training strategies for the thermal mode of the ISU, to impart the new guidelines and techniques;
- Produce still photographs and video tape materials for training the use of thermal cues in detection and identification;
- Develop training packages for use in resident courses and for exportation to BIFV tactical units.

The following sections describe the approaches employed to reach these objectives, the results of field testing, and conclusions and recommendations. Brief summaries are presented here; Annex 5 provides the details of the second year work in this research area.

Approach

Phase I. The first step was to acquire hands-on experience with the equipment. The aim of this first phase was to systematically establish the capabilities and limitations of the ISU (thermal mode). This exploratory work was accomplished at a Fort Benning BIFV range over a two-week period (spring, 1985). ARI/Litton staff and active duty military personnel served as operators, utilizing the ISU of three BIFVs on a rotating basis. Four target vehicles were rotated among 11 downrange positions at ranges from 675-4200 meters. This arrangement was suitable for obtaining observations through the ISU of single targets, in varied aspects at varied ranges, with varying ambient temperatures and weather conditions.

Each time a new target array was established downrange, operators scanned the area for thermal signatures. Observers were encouraged to devote time to

manipulation of the controls to obtain the most well-defined thermal picture. When an object of interest was detected, observers made written notes on all visual cues, indicating features they felt they could identify, sketching the visible mass, and recording details on the performance of the controls. Also, azimuth and estimated range were recorded. If operators felt they could classify and/or identify the object, this information was recorded.

After operators had rotated to several BIFVs and different target arrays, comments were solicited about variablity between ISUs and variation of each ISU after extended use. Finally, observations on operator fatigue (in particular, eye strain) were recorded.

The accumulated observations were analyzed for consensus judgements and emerging patterns of operator behavior. It was determined that there is variability in the performance of the thermal control knobs (focus, brightness, and contrast) between individual vehicles. The performance of the thermal mode in any single BIFV will vary also, with extended use, after movement, and with ambient temperature change. Finally, the characteristics of the image vary widely according to the magnification setting (4x or 12x) and the polarity setting (black-hot or white-hot).

The capabilities investigation also indicated that there are differences in individual abilities to analyze thermal cues. While almost everyone can detect "heat spots," even at very great ranges, observers vary considerably in their abilities to further characterize or describe the heat spots. Individuals with a background of experience in thermal use were better able to describe the target characteristics they saw, and relatively naive observers became better at perceiving and describing cues over time.

A major problem which surfaced during this phase of the investigation involved range determination. It became apparent that, even when personnel are experienced at range estimation in other contexts, it is almost impossible to estimate range under thermal conditions without practiced use of reference points or terrain association methods.

However, even given the problems reported above, the ARI/Litton researchers did find that the BIFV ISU has the inherent capability for thermal object detection and classification at ranges in excess of 2000 meters, and detection is possible at ranges up to 4200 meters. It was concluded that the issue is apparently not the inherent capabilities of the ISU (thermal mode), but the current lack of user knowledge and skill in employing this versatile and sophisticated equipment. Effective thermal viewing requires setting polarity, focus, brightness and contrast to optimize the thermal display for the range being observed. Since many conditions impact on the quality of the thermal image within the sight at any one time, it is not possible to set and forget. Adjustments will have to be made rapidly and efficiently under combat conditions.

The massed practice achieved during this initial phase did produce the emergence of operator consensus on efficient scanning techniques and techniques for manipulation of the thermal sight controls. These findings were

incorporated in the planning for the next step, which involved development and evaluation of improved thermal training content, training aids, and training delivery strategy.

The final aspect of the first phase work involved the objective of producing updated (and BIFV-specific) thermal training materials. The conditions described above provided an opportunity for testing the feasibility of capturing actual BIFV ISU thermal sight pictures, using both 35mm still photographs and newly available video taping equipment (known as through-the-sight video). This work demonstrated the feasibility of obtaining high fidelity reproductions of the thermal images as they appear to the operator. The photographic techniques for obtaining the quantity and quality of materials required for inclusion in a training package were perfected. Plans were formulated for production of these materials during the second phase.

Phase II. Development of training for the BIFV ISU (thermal mode). Procedures for operating the ISU in the thermal mode, designed to maximize the capabilities of the equipment and minimize limitations, were developed. Data and rationale for the procedures were derived from multiple sources:

- Review of related research;
- Prior military experience and lessons learned;
- Hands-on experience with the idiosyncrasies of the BIFV ISU (from Phase I work).

The next step was to develop a lesson plan for training in the use of the improved thermal sight procedures/guidelines (see Rollier, 1985c for the training package). The initial portion is designed for delivery as a class in a bleacher situation. The lesson plan sequence begins with turret familiarization using a mock-up of the gunner station as a training aid. The locations of the thermal control knobs are explained and guidelines for manipulating focus, brightness, contrast and polarity, either singly or in various combinations to produce the optimal thermal image, are demonstrated by the instructor. Next, general guidelines and techniques for sector scanning are explained. The class is concluded with lecture/discussion focusing on the construction and operational employment of a range card, as an essential reference tool for estimating range when using the thermal mode of the ISU. The second portion of the lesson plan is implemented with hands-on experience in the turret for each individual. Teaching points presented in the class are reinforced through coaching from an instructor, covering both the thermal sight (nomenclature and operation), and the principles of the range card. The total length of the instruction is 3.5 hours, apportioned as follows: (a) nomenclature and operation of the thermal controls--60 minutes; (b) Range cards, sector scanning and ranging--90 minutes; (c) hands-on and coaching in the turret--60 minutes.

Pilot testing of the lesson plan was done using civilians who had no prior experience with the ISU or thermal imagery. The comments and post-training performance of these individuals were used to adjust such aspects of the training as sequencing, vocabulary, and coaching techniques. The finalized lesson plan is presented in Rollier, 1985. Also presented are exhibits of

special texts for range card construction, scanning techniques and manipulation of the Thermal Sight controls, to be included in the training program.

Evaluation of the Improved Training For the BIFV ISU (thermal mode). Field testing of the BIFV-specific guidelines for thermal sight employment, and the training developed, was designed to compare performance of individuals trained by conventional techniques to that of novice operators trained by the ARI/Litton approach. For this comparison, two groups of operators were assembled and performance with the thermal mode was measured under controlled test conditions.

The Experienced Gunners group consisted of 24 individuals assigned to Delta Company, 1st Battalion, 29th Infantry Regiment, Fort Benning. These individuals were Bradley Gunner qualified, familiar with gunnery and, therefore, with the use of the thermal sight. By previous training received in resident courses and BIFV units, this group experienced the conventional instruction in thermal sight use and had opportunity for practice in operational settings.

The Novice Group consisted of 24 individuals, also from Delta Company, who were not turret-experienced. This group had not received prior instruction in thermal sight operation and were naive subjects.

Evidence for the validity and utility of the thermal guidelines and training developed by ARI/Litton would be supplied by the following outcomes;

- After receiving the proposed instruction, the Novice Group can perform at a level equal to or greater than the performance level of the Experienced Gunner Group;

- The Novice Group can improve performance when retested on the following day (a practice effect);

- The Experienced Gunner group can benefit from the modified instruction to improve performance on retesting.

The controlled test conditions established to investigate these hypotheses are presented in detail elsewhere. A brief overview is presented here. The test site was a Fort Benning range used exclusively for BIFV training; a bleacher area was available for conduct of the intitial portion of the modified training program. Six vehicles with fully operational ISUs were placed on-line on the firing pad to serve as test stations. The azimuth and range from each vehicle to each of 18 preselected target position was determined, two alternative target scenarios of nine positions each were created, and nine military vehicles of varying type were placed downrange. Maximum target range was 2065 meters and the minimum range was 895 meters. The maximum range was the furthest distance at which a target vehicle could be sited.

The first day test procedure for the Novice Group began with an orientation on the purpose of the test, a safety briefing, and individual assignments to one of the six test station vehicles. This was followed immediately by administration of the ARI/Litton modified training on thermal sight manipulation and range estimation, exactly as described above. Each individual was given a range card template and an appropriate amount of time to complete a

range card according to the instruction they had received. The group then remained in an off-range area until on-set of darkness, when target vehicles were moved into place according to one of the two target scenarios. Post-training performance testing began after optimal limited visibility conditions emerged.

Each novice performed individually in the gunner's position of his assigned vehicle, under the observation of the research team member assigned to that vehicle. The thermal sights were pre-set on low magnification and white-hot polarity, and the focus, brightness and contrast knobs were set at the right extent of their rotation range. The observer instructed the subject that multiple target vehicles had been placed down-range to the left, center and right of the sector. The task was to scan to detect these targets, optimizing the thermal image each time. When the subject discovered a target, he was to indicate this to the observer, determine the azimuth and estimate the range by reference to known distance points entered on the range card. He was asked to make note of all thermal cues, draw a sketch of the image, and name the vehicle if he could. After information had been recorded from one detection, the test subject continued to the next detection, stopping the procedure when he felt he had detected all the targets. Subjects were not told the number of targets, their locations or vehicle types. They were allowed to work at their own pace with an upper time limit of 60 minutes in the turret at the test station. They were told that elapsed time was being recorded, and were encouraged to work steadily without rushing.

The procedure for the Novice Group on the following night omitted the training period and duplicated the test station portion of the first day. The second target scenario was used during the performance testing. The order of testing was reversed so that individuals who had performed during the final period of the preceding night were now tested during the first period.

For the Experienced Gunner Group on their first day, the procedure for the performance testing in the turret was identical to that for the Novice Group. The daylight portion differed in that this group received no instruction and was told only to use the template they were given to make a range card, using whatever techniques that had been learned during their previous BIFV and/or infantry training. The second day of testing for the Experienced Gunner Group began with presentation of that portion of the ARI/Litton training related to the idiosyncrasies of the BIFV ISU thermal control knobs and to construction and employment of range cards for use during limited visibility periods. Performance of this group was then retested after darkness on the second day, using identical testing procedures, but with target vehicles placed in different locations and at different ranges.

To recap, the four-day testing period was designed to established controlled conditions for measuring thermal sight operator performance. The two-day experience for the two test groups differed, as is shown in the matrix below.

Table 2

Summary of Experimental Procedure

	Day 1	Day 2
Novice Group	A. Training/test	B. Performance
Experienced Gunners	C. Performance	D. Training/test

The benefit of the proposed training can be estimated by comparing the Day 1 performance of the two groups (A compared to C). The full effect of the modified training with additional practice can be estimated by comparing the Novice Group performance levels over the two-day period (A compared to B). The degree to which "previously-trained" individuals would benefit from the modified training can be estimated by measuring any improvement in performance by the Experienced Gunner Group over the two-day period (C compared to D).

Finally, the four-day period afforded an opportunity to produce 35mm and video-tape reproductions of actual thermal imagery, in accordance with the future objective of producing an improved and exportable thermal training package. A seventh BIFV was utilized as a camera vehicle. Variety was insured by the fact that nine different vehicles were available at varying ranges and azimuths to the camera vehicle, under varying weather and ambient temperature conditions. The process of filming in no way impacted upon the test subjects.

Amplification of this brief overview can be found in Rollier, 1985, with exhibits of observer and subject data forms, the target list and scenarios, and the training lesson plan. The following section summarizes the results of the data analysis.

Evaluation Results

The methodology described above was designed to produce four major measures of operator performance when employing the thermal mode of the ISU. These performance indicators are described below.

Detection. Each time the subject indicated he had detected a target, the azimuth to the heat source was recorded. A correct detection was scored if a target was emplaced at that point according to the target scenarios used. A percentage score was calculated for each subject by comparing the number of correct detections to the possible number; separate percentages were calculated for the two days. A mean percentage and standard deviation for each group (Novices and Experienced Gunners) was then calculated for each day.

Identification. For correct detections, the percentage of time the subject correctly identified the vehicle he had isolated in the sight picture was

calculated. Mean percentages and standard deviations were calculated for each group separately for each of the two days.

Thermal Cues. Another task required of each subject was to identify and report features of the detected vehicles which he could distinguish within the thermal image. Examples of cues are the engine area, tracks or wheels, turret, and hatches. The mean number of cues reported for each group on each day was calculated.

Range Estimation. Subjects estimated the range to each detected vehicle. Range reported was compared to the known range to produce an error score for each detected target. For each subject, the total error was computed by summing the over-and-under estimations of the true range across all targets detected by that subject, and a mean ranging error (in meters) was determined for each day separately. Overall means for the two groups on each day were calculated.

Planned Comparisons. For each of the performance measures described above, an analysis of variance for repeated measures was performed, and detailed presentation of these statistics are in Rollier, 1985. In each case, the comparisons of interest were: (a) the performance of the Novice Group on the first day after receiving the ARI/Litton training compared to the first day performance of the Experienced Gunners who did not receive the training first; (b) the performance of the Experienced Gunners on the second day after receiving training compared to their own first day performance levels; (c) the performance of the Novice Group on the second day of practice compared to their first day performance. Table 3 below summarizes the data for the four performance measures (by group and by day), showing the obtained means and the direction of differences.

Table 3

Various Performance Measures

Performance Measure	Novice vs Gunner	Day 2 vs 1 (Gunners)	Day 2 vs 1 (Novices)
Detection (% correct)	70 > 54	78 > 54	86 > 70
Identification (% correct)	56 > 26	52 > 26	61 > 56
Thermal Cues (# reported)	11.9 > 4.6	11.5 > 4.6	11.4 < 11.9
Range Estimation (error in meters)	355 < 448	418 < 448	409 > 356

The comparisons presented in the first column of the table shows that the first day performance of the Novice Group exceeded the performance of the Experienced Gunner Group for each performance measure. The differences in the means is significant in the case of Detection, Identification and Thermal Cues (Rollier, 1985 has ANOVA tables). Though Novices performed the range estimation task slightly better in that the mean error for this group was some meters less, the statistical analysis of this difference did not reach the criterion level necessary to consider this a reliable or repeatable difference.

The performance of the Experienced Gunner group improved the second day, as is indicated by the direction of differences in the second column; the difference is statistically significant for the first three measures and the difference in range estimation error is non-significant.

Finally, the data in the third column indicates that Novices benefited from an additional day of practice of the principles taught during the ARI/Litton training program; the percentage of Detections and Identifications increased significantly. However, the number of Thermal Cues reported by Novices and the mean Range Estimation error was essentially the same for the two days.

Discussion

The field research determined that BIFV unit personnel presently have great difficulty in performing tasks that involve manipulation of the ISU in the thermal mode. Further, user attitudes typically attribute the problem to

inadequacies in the thermal sight itself. The research team acquired systematic hands-on experience with the equipment and determined that, while there are serious human factors problems with the design (the sight picture controls are prime examples), the equipment could perform much more reliably than commonly believed. Therefore, it was determined that a training solution to the present performance deficiencies should be pursued prior to examining an equipment development effort.

The research team analyzed existing training in this area and then drafted an improved training package. It was judged that training in the essential principles for using the sophisticated thermal sight could be accomplished in a relatively short block of training--only two hours of instruction and one hour of hands-on familiarization. The initial form of the ARI/Litton thermal training was then subjected to a stringent evaluation design.

For the evaluation design, the data of interest was the performance level of a group of young soldiers having little military experience in general and specifically no prior turret training or experience--after they had received training in thermal sight operation through the presentation of the ARI/Litton approach. Overall, it can be concluded that the post-training performance of the Novice Group was highly satisfactory (for example, 70 percent of the targets were detected immediately following the training period and this improved to 86 percent on the second day of practice).

The post-training performance level of the Novices becomes more meaningful, however, when it is compared to the performance of a contrasting group. Therefore, the evaluation design included a group of soldiers who had longer time in service and a great deal of BIFV-specific training intended to prepare them to serve in the capacity of Bradley gunner in combat. It was presumed that the "post-training" performance of this experienced group should be consistently high if present training approaches are adequate. The measured performance of the Gunner Group provides a challenging baseline for interpreting the performance of Novices after receiving the new training approach. Each aspect of the overall performance of the two groups is discussed below.

Thermal Sight Manipulation. Portions of the ARI/Litton proposed training program dealt specifically with techniques for scanning in the thermal mode to insure efficient detection of objects of interest. The data presented above indicate that the Novice Group was able to detect a greater number of the thermal targets from the array presented to them than did the group of gunners when they performed the same task. (Experienced gunners should out-perform novices by a significant amount in this area, because of prior service and training.)

Manipulation of the thermal image controls to obtain maximum clarity of the thermal image was another significant portion of the training package. Novices reported a greater number of Thermal Cues and achieved higher percentages of correct Identifications of the detected targets than did the Gunner group. It can be concluded that effective techniques of employing the thermal mode of the BIFV ISU for target detection can be imparted to inexperienced soldiers in a relatively short block of instruction and that gunners trained by currently available methods can also benefit from the improved training program.

The work reported in this section bears directly on the thermal sight issues noted by the research team during the problem analysis phase of the project. The impetus to the work was the perception of users, as reported to team members during visits to units, that the capabilities of the thermal sight were limited to very short ranges. The demonstrated success of the ARI/Litton training package in enabling untrained individuals to perform Detection and Identification tasks as well or better than experienced gunners, indicates that training solutions to the existing field performance deficiencies during limited visibility conditions will be more immediately productive and cost effective than equipment modifications.

Range Estimation in the Thermal Mode. The third major portion of the training program dealt with the construction of high quality range cards and the use of this technique in performing range estimation at night. Range estimation is a task which the Army has found consistently difficult to teach, even when visibility is optimum. Historically, however, the training received by earlier generations of soldiers throughout the Army placed much more emphasis on the value of the range card than is currently the case in institutional and unit training. This observation is supported by the findings of the research team on-site during BIFV unit field exercises in USAEUR and CONUS, where failure to make and use a range card was a consistent occurrence. The replies of soldiers to queries indicated that prior training had not adequately demonstrated how and why the range card is an essential job performance aid for range estimation.

The research team focused on development and evaluation of improved range card training in this study after considering alternative solutions to the range estimation problem. One alternative approach to upgrading performance of the range estimation task focuses on reticle design, providing built-in mechanical aids, and the optimal techniques for their use. The companion report that focuses on gunnery issues treats work performed in the latter area to develop improved ranging techniques with the reticle choke-sight, for example. At present, no research exists comparing range estimation performance with this approach to techniques based on range card data. In particular, the relative advantages for limited visibility conditions is an open question. A second option involves advanced laser technology for automatic range finding equipment. Whether (and when) developments in this technology will provide a widely available and battle-proof piece of equipment is open to question, also. The back-up system which is the soldier trained to perform the task, using performance aids such as a range card, will always be required. The high level of inaccuracy that presently exists points to the need for further research and development.

The evaluation results presented above do not clearly support the conclusion that the ARI/Litton approach to range estimation training represents an improved training strategy (in contrast to the findings relative to the Detection and Identification tasks). However, the data comparing the performance of the Novice Group after receiving the range card training shows that their ability to accurately estimate range to a target appearing as a thermal image in the ISU sight is essentially equal to that of the Experienced Gunner Group.

In any case, the mean error in range estimation far exceeds tolerable limits for both groups. The Soldiers Manual standard for range estimation is 200 meters under daylight conditions when the task is performed using such techniques as the "football field method" or the "binocular reticle technique." No standard which is specific to use of the ISU in thermal mode is known to exist at present. In the opinion of the research team, the tolerable error must be reduced for the support of effective battlefield surveillance and gunnery, and more effective training can support a more stringent standard. Correct scanning techniques should enable the operator to determine that the detected object (in relationship to a known distance reference point previously entered on the range card) is within a given 500 meter interval; e.g., detection of an object just beyond the 1000 meter scanline places it in the 1000-1500 range. A key element in the ARI/Litton approach is the selection of a minimum of 2 reference points at each 1000 meter interval. This action, alone, provides sufficient reference points to produce distance estimations well within the 200 meter boundary. Further practice with exact placement of the object in relation to key terrain features and man-made reference points should bring the mean estimation error even lower. A secondary benefit of emphasis on range card preparation and use, would be practice and improvement of the gunner's perception of the proportions/characteristics of the terrain in his sector of fire.

It was concluded that additional research and development must be conducted to increase ability to use the range card data for accurate determination of the location of a target in relation to reference points at known distances. The portion of the modified training program related to range estimation was subjected to its maximum challenge by asking soldiers to apply the training immediately to limited visibility conditions. The procedure of relating objects appearing in the thermal sight picture to surrounding terrain and accurately locating positions on the range card is difficult to master. The design of the evaluation procedures did not permit opportunity to practice and, during the evaluation data collection period, soldiers had limited numbers of trials to practice (a maximum of eighteen if all targets were detected). Additional practice may be necessary before the integrated skills of range scanning, identification of thermal reference points and optimum utilization of range card data begin to show an effect in terms of improved range estimation performance.

After analysis of the present results, the research team concluded that the keystone for BIFV range estimation training should remain instruction and practice in the effective construction and use of range cards. Revision of the training program should take the approach of additional daylight instruction on range card techniques, with enhanced practical exercises giving the soldier immediate feedback on the degree and direction of range estimation error after each trial. Continuation of the training with transfer to the thermal mode should also emphasize feedback and practice of aspects of the range estimation task specific to the thermal condition. Known techniques for constructing training areas for range estimation on terrain available for institutional and unit training should be restored to the training package.

Directions for Future Work. The results of the work reported here establish the foundation for continued developmental efforts. The overall effectiveness of the ARI/Litton thermal training approach is apparent and a number of revisions which can be made in minimum additional time have been identified. Specific revisions are recommended in the next section.

Secondly, the exploratory work with the through-the-sight video and 35mm slides of thermal images was successful in perfecting techniques for producing high quality visual aids that can be included in the next generation of the thermal training package.

The added experience gained by the research team during the evaluation process generated ideas for expanding the data base relative to the ISU thermal image. Systematic determination of the effect of variables such as sight magnification and polarity, range to the target, target cover, and target camouflage and concealment are potential areas for basic research and incorporation of the results into the training in thermal sight operation.

Finally, the demonstrated suc n developing individual thermal training supports movement to the next st ollective training in unit procedures for coordinated surveillance of the battlefield and collection/interpretation of thermal information obtained by individual squads from different positions on the battlefield.

Specific recommendations for future work are presented in the following subsection.

Recommendations

The results of the field evaluation of the ARI/Litton thermal training package establish the need for implementation of the recommendations which follow. The work completed in this phase has both immediate utility and implications for needed future work. For the near term, it is recommended that:

- Revisions and additions to the thermal training package be made immediately, to include

  (1) Practical exercises on scanning techniques,

  (2) Instructional procedures to insure use of the range card for every target range estimation trial,

  (3) Use of the special text for conduct of instruction on the range card and its use,

  (4) Use of the special text for conduct of instruction on thermal sight manipulation procedures;

- The revised training package be made available for trial at selected institutional and unit training sites, to include

  (1) The Bradley Gunner and Bradley Commanders Courses,

  (2) The 1st Bn, 29th Infantry Regiment,

  (3) Selected company level BIFV tactical units;

- Commanders emphasize the need to train thermal sight manipulation and range card skills and establish suitable incentives for mastery.

For future work, it is recommended that:

- Research be conducted to increase the data base specific to the BIFV thermal mode of the ISU--including but not limited to investigation of the effects on the ISU thermal image of important variables such as magnification and polarity, range to the target, and target cover, camouflage and concealment, and the impact of obscurants and weather variables such as fog, rain, snow;

- An improved squad and platoon surveillance plan be perfected and field tested;

- An expanded and fully exportable BIFV thermal training package be developed, incorporating the results of the additional work, as follows,

  (1) Full utilization of the expanded thermal data base,

  (2) Training addressed to thermal target detection for camouflaged/concealed targets,

  (3) Improved range estimation procedures for tactical target acquisition and gunnery,

  (4) Utilization of visual aids in the form of systematically programmed video tape of thermal images and 35mm slides obtained through the use of through-the-sight video equipment,

  (5) Sequenced individual training in thermal sight operation and collective training of small unit surveillance techniques.

The Bradley Commanders Course

Problem Definition

The BIFV Commanders Course presents resident instruction for squad leaders, platoon leaders and company commanders. Attendance is based on current assignment to a BIFV unit, or designation for such assignment. The course content covers a range of subjects related to BIFV maintenance, gunnery and tactics. This BIFV transitional course was developed to provide trained individuals for the newly fielded Bradley being received by units in the field. It, therefore, has a short history and is still evolving. Responsibility for instruction was originally shared by two entities within the U.S. Army Infantry School. Instruction in gunnery tasks and MOS 11M Skill Level 1 tasks was presented by Weapons Gunnery and Maintenance Division (WGMD). Tactical instruction (the second major focus in the course) was presented by Tactics Division, Combined Arms and Tactics Department (CATD). As part of a general reorganization, the 29th Infantry Regiment assumed administrative responsibility in the latter part of 1984.

The Commanders Course was reviewed by the research team during the problem analysis phase at the same time other Bradley-specific courses were examined (i.e., the Drivers Course, the Gunners Course, and the Master Gunners Course). At this time also, all officer and noncommissioned officer career courses presenting instruction relevant to BIFV operations were examined. This information permitted development of general and specific data about current resident BIFV instruction that was compared next to the training requirements observed during on-site visits to BIFV units. Results of the overall training review were documented as part of the problem analysis phase (see Reference List.)

At that time, the research team noted that tactical employment of the emerging BIFV system (as a new concept impacting on conventional mechanized infantry tactics) was not a training focus in any resident courses other than the BIFV Commanders Course. Recommendations related to future directions for work designed to improve instruction in this area were presented. In addition, coordination between ARI and personnel of WGMD was instrumental in identifying a number of course-related issues that had been isolated independently by the two groups. These included, for example, questions related to optimal class size, course length, student/instructor ratios, evaluation strategies and task standards.

Therefore, the Commanders Course was selected by the ARI/Litton research team as a topic area for further exploration during the second phase of the project. The important role played by the Commanders Course within the educational system that prepares individuals for service in BIFV units, the identified potential for upgrading the course, and the desire for additional data expressed by the proponent, were factors qualifying it as a candidate for further work during the test and evaluation phase of the ARI/Litton project. A brief summary of the work done in this problem area is presented here; a complete treatment can be found in Perkins & Rollier, 1986.

Approach

The overall problem analysis approach included examination of literature relating to the BIFV; e.g., field manuals, technical manuals, training circulars, and student texts. Therefore, the research team had assimilated essential background prior to focused review of the Commanders Course.

The first step in the course analysis was to obtain and review written material of the following types:

- The Program of Instruction;
- Lesson Plans;
- Training Aids;
- Student Advance Sheets;
- Evaluation Plans;
- Historical Test Data.

These sources define the intended structure of the course in terms of tasks to be trained, the training conditions, performance standards, sequence of training, training time devoted to each task, method of training (e.g., lecture, practical exercise), integrated learning of related tasks, student performance criteria for graduation, and resources required for training. Advance sheets, and the references listed therein, define the preparation and prerequisite learning required of students prior to attending a particular class or block of instruction.

The next step was to observe the actual implementation of the intended course plan. One complete iteration of the course was monitored, the tactical portions of two additional courses were observed, and gunnery training was studied in a total of six iterations of the Commanders and Gunners Course (the latter presents gunnery training very similar to that found in the Commanders Course). The observations were completed in the 1984-85 time frame. Observation focused on issues related to student/instructor ratio, actual training time devoted to a task compared to the POI-specified time frame, performance feedback available, use of concurrent training when required, and quantity/quality of actual student participation during the training.

The purpose of the observation phase was to obtain information on student performance and the effect of course organization on training effectiveness and efficiency. Therefore, the observer avoided activities which would disrupt the normal flow of instruction. The observer did not assume the role of a student during scheduled training time but did acquire hands-on experience with tasks and equipment after the completion of instruction or testing. Similarly, the opinions of students, instructors and course administators were solicited at appropriate times throughout the observation period (e.g., at the end of the training day).

Finally, the data base accumulated during the review was related to observations obtained during on-site visits to BIFV units. This latter source of information indicated areas where altered or additional training focus was required. The research team then analyzed the data obtained from multiple sources to formulate conclusions and recommendations relating to the Commanders Course. These results are presented below.

Conclusions

It can be concluded that instructors and administrators involved in the BIFV Commanders Course are highly competent subject matter experts and motivated to provide the most effective and efficient instruction possible. It was evident that the training cadre are doing more than a job; they will do whatever is necessary to provide the best possible training. There has been an enormous improvement in training efficiency over the two years of observation. The course has quickly passed the stage of infancy because of the quality of the instructor personnel dedicated to it.

The overall quality of the course is very high considering its scope and the relatively short period since its inception. A major portion of the course has achieved a level of quality where minimal improvement can be expected. For example, training efficiency was extremely high during the first two weeks when instruction focused on MOS 11M Skill Level 1 tasks and BIFV maintenance tasks.

However, the review conducted by the ARI/Litton research team did identify a number of areas where constructive interventions would have high payoff potential. These relate generally to augmentations of or additions to certain course content blocks, to greater integration of related course content to reflect the interactions among separable tasks, and to certain administrative aspects of the course. Detailed conclusions and supporting materials are presented in Annex 6 and summarized here.

Course Content. It was determined that the content areas listed below were either omitted or inadequately treated in the Commanders Course.

- Practical exercises in the use of the thermal mode of the ISU;
- Practical exercises in target acquisition, identification and classification;
- Preparation and employment of range cards and sector sketches;
- Range estimation;
- Execution of fundamental gunnery skills and techniques;
- Execution of fire commands at squad and platoon level;
- Knowledge of 25mm ammunition ballistics characteristics;
- Combat loading and familiarity with Basic Issue Items and the Additional Authorization List;
- Techniques required for mounted land navigation;
- Relationship between communication hook-up alternatives and impact on command and control;
- Integration of STANO devices and the BIFV ISU into a limited visibility surveillance plan;

* Combined arms operations.

As stated, the rationale for revising the content of the Commanders Course to include augmented treatment of these areas, is given in Perkins, 1986. report. Additional material presenting original work performed by the ARI/Litton research team in these areas can be found in two previously released documents (see References), in other sections and annexes of the present report, and in the companion report treating gunnery procedures. These sources will provide the necessary background material for appropriate revisions to the Commanders Course content. Such revisions also would have ramifications for other resident courses and unit training practices.

Course Administration. The size of the classes for the several course iterations observed varied from 32-49. Intervals between iterations of the course and the field requirements for graduates of the course determine the size of any given class. However, it should be noted, that some individuals attending the course have received NETT training, and the common reason for attending cited by these individuals is to obtain the gunnery training. These students should receive a lower priority for admittance to the class than those who have not received any BIFV training.

After observation of several iterations, it was concluded that quality of instruction in the Commanders Course is particularly affected by class size, due to the nature of the course itself. An essential element throughout the course (to include the tactical portion), is the opportunity for students to practice training tasks through hands-on interaction with actual BIFV equipment or training devices. The available training resources, therefore, determine the practical upper limit or optimal class size.

The number of BIFVs which can be managed in the field training environment is one determining factor. Over the two years of observation, the number of BIFVs utilized at one time for training has not exceeded a maximum of 10 vehicles. One assistant instructor (AI) per vehicle can be utilized productively. It was concluded that the observed maximum is, indeed, the practical upper limit, due to considerations of availability of operational vehicles, range and training area limitations, safety, and training cadre available.

An overwhelming majority of the tasks trained in the course require an operational BIFV as a training station. The number of available vehicles and AIs, therefore, impacts upon the student/instructor ratio. The configuration of the vehicle and its equipment, also, impacts upon the number of students it can serve as a training station at one time. For example, many of the trained tasks for which hands-on experience is essential, involve the technologically sophisticated turret of the BIFV. Available space in and around the turret is limited to the gunner's and commander's seats inside and the two hatches outside. Even with three students and one instructor in these positions, students are not participating actively in the training throughout the instructional period.

The negative impact of excessive class size on training efficiency was most clearly observable during the course iteration for which an enrollment of 49 students created an instructor/student ratio of about 5 to 1. Impact on the

students, themselves, was particularly noted during live fire gunnery when students experienced little opportunity for direct participation in the training.

In summary, class size (and, therefore, student/instructor ratio) has an upper limit in the Commanders Course which is dependent on multiple factors. The estimated number of students that can be trained effectively in one group was analyzed on a task-by-task basis. The majority of tasks require a 3 to 1 ratio.

Course Length. It was concluded that there is no current justification for subtracting any scheduled training hours. Determination of optimal course length is dependent on the time and resources required to augment the course content to include all the required training objectives for a BIFV commander. However, any additional time requirements for course content revision could be partially off-set by efficient organization of concurrent training during the live fire portion of the course. Range restrictions during live fire gunnery can create a bottleneck in training efficiency unless concurrent training is utilized in an optimal manner.

For live fire gunnery, the POI specifies 130 training hours to be administered over a 10-day block. It was estimated by the observer that students actually spend about 3 hours of training with hands-on practice of live fire. The potential for limitation on student participation during live fire gunnery creates the need for extensive concurrent training if students are to be meaningfully occupied. Improvements in utilizing this time for training in content areas that are important for training BIFV commanders were noted over the observation period. However, the POI does not reflect current or planned uses of the concurrent training time.

Student Evaluation Practices. The BIFV Commanders Course is the only resident course that trains the BIFV leader to use and maintain his BIFV weapons and to plan and execute the fundamentals required to command his unit. However, the BIFV Commanders Course neither qualifies the student as a gunner nor evaluates his tactical capabilities. Students are aware of this, particularly as it pertains to the limited tactical instruction given in the course.

Review of the POI revealed that the gunnery training objectives did not cover certain fundamental skills and techniques, to include application of appropriate lead and reverse lead, using shot control to achieve firing of sensing rounds and 3- to 5-round shot groups, target tracking before and during engagement, and burst-on-target adjustments. Potential areas of training improvement are recommended in the companion ARI report on gunnery procedures developments and training (see References). After the fundamentals of gunnery have been trained during the conduct of the course, then it is feasible to consider gunnery qualification in the BIFV Commanders Course.

Secondly, the POI does not require students to demonstrate mastery of the tactical training objectives of the course. Only three days are devoted to tactics and this occurs late in the course. Graduation requirements have already been met before the tactical instruction is presented and students tend to view this portion of the course as an afterthought. The POI for tactical

instruction in the Commanders Course states that the intention is to focus on those capabilities that are peculiar to BIFV operations. However, a major portion of the classroom instruction was observed to focus on general mechanized infantry operations; material which is redundant as a result of prior training for most of the students. While mechanized infantry tactics are similar for the M113 and the BIFV, the Bradley creates unique challenges in planning for and control of its firepower. Gunnery and tactics are too "cleanly" separated in the BIFV Commanders Course; integration of gunnery techniques and information as they impact on tactical considerations is not accomplished. The development of a tactical evaluation procedure that requires the potential BIFV commander to demonstrate mastery of critical tactical knowledges and skills would facilitate restructuring of the tactical POI of the Commanders Course. It would help also to redress the present perceived imbalance of training hours that tends to deemphasize those tasks which are specific to the BIFV commander.

Recommendations

The conclusions presented above represent a condensation of the detailed course review data that is available in Annex 6. Additionally, information which impacts on projected improvements in the training of potential BIFV commanders can be found in other sections of this report (see the sections titled Thermal Mode of the ISU, Night/Limited Visibility Training, and Platoon/Squad Leader Span of Control).

The conclusions provide the basis for formulation of specific recommendations for course improvement in the areas of gunnery, tactics and general course administration. The recommendations related to gunnery fundamentals are not presented here; they require the comprehensive treatment which is given to them in the companion report on gunnery procedures (see Reference List).

Nine recommendations related to BIFV Commanders Course administration and tactics instruction are presented below. Perkins 1986 contains the rationale for each recommendation and guidelines for implementation.

- Set maximum class size at 30 individuals and closely regulate it;
- Maintain the current course length;
- Revise the live fire annex of the POI to reflect accurate description of both the live fire and concurrent training objectives;
- Add the following content to the POI, to be taught concurrently during the live fire block of instruction;

  1. Ballistic characteristics of 25mm ammunition;
  2. Mounted land navigation techniques;
  3. Simulated gunnery training using U-COFT;
  4. The training of the Master Gunner and his responsibilities in the BIFV unit;
  5. Combat loading;

6. Competitive uploading exercise for 25mm ammunition;

7. Thermal target acquisition and identification.

- Develop and implement a BIFV tactics test with a passing grade score required for graduation;

- During tactical training, have the Chief, Tactics Division, CATD, USAIS present and discuss current critical BIFV tactical issues;

- During tactical training, have the Armor Liason Officer to the Infantry School present and discuss the role of armor in company team operations;

- At the conclusion of the course, have the Commander of the 29th Infantry Regiment deliver a presentation on critical considerations, situations and problems that exist in BIFV units;

- Develop and implement a night defense practical exercise where range cards and sector sketches are used for target acquisition and fire planning and control.

Training For Night/Limited Visibility Operations

Problem Definition

The ARI/Litton research team conducted an up-to-date assessment of the Threat during the problem analysis phase of this project. The focus was upon those aspects of Soviet organization, tactics and techniques which have the greatest impact upon the employment of the Bradley Infantry Fighting Vehicle.

Soviet operations are characterized by constant activity day and night. Night insertions and extractions of mobile detachments by air, land or water are likely. These forces may be large to provide extra firepower to the rear or small to collect additional reconnaissance information. Night operations are viewed as extensions of daylight activities. Limited visibility operations can be expected when Soviet objectives have not been achieved before nightfall.

Soviet use of limited visibility conditions is comparable to use of an offensive weapon. For example, the Soviets employ smoke in three ways: (a) screening smoke is used to cover the movement of Soviet forces and hinder enemy target acquisition efforts; (b) deceptive smoke is used to mislead the enemy as to the true objective and avenue of approach; (c) blinding smoke is used on the objective to blind enemy gunners and degrade their sighting systems.

Soviet forces are well practiced in many aspects of the training required to implement their limited visibility doctrine. Lengthy marches, resupply of troops and weapons, movement to alternative firing positions, and construction of fortifications are emphasized and performed at night. During the night, reconnaissance and security activities are increased. March columns are shortened and extra traffic controllers are used. Observers with night vision goggles are dispersed among the units.

The Threat assessment served as a perspective for research team members during the field trips to observe BIFV units in USAREUR and CONUS. It was noted that there was a particular lack of awareness of the need to train for reaction to Soviet doctrine pertaining to limited visibility operations.

Comments to ARI/Litton research team members from company and higher level commanders indicated that they believed subordinate units were conscious of the problems associated with night operations and were taking proper action. However, the actual field observations revealed a number of serious deficiencies. It is difficult for mechanized Company Commanders to conduct operational inspections at night when platoon elements are widely dispersed and movement is difficult, occasionally dangerous, and always produces noise. Therefore, command visitations are rare and perceptions of unit readiness to operate at night do not coincide with reality.

It was observed that units failed to bring night vision goggles, Starlight scopes, Dragon night sights and other Surveillance, Target Acquisition and Night Observation (STANO) equipment to the field for exercises. Only the BIFV integrated sight unit (ISU) and the driver's night sight were employed in most night operations. Occasionally, an individual platoon leader or a company commander used the AN/PVS-5 night vision goggles for relatively short-range

surveillance or to check a map. However, night vision devices were not given a high priority by any of the forces observed.

Although training directives dictate that one-third of all tactical training be conducted under limited visibility conditions, examination of current unit training schedules indicates that this is not being done. Field personnel queried by research team members indicated that the conduct of training specific to limited visibility conditions is hampered by the lack of adequate guidance on the optimal content and methods for such training. Research team members verified that the BIFV community does not have a Program of Instruction (POI) specific to limited visibility conditions.

Therefore, the objective of preparation of an up-to-date program of instruction for night operations training was identified as a high payoff research topic to be pursued by the ARI/Litton research team during the second year of the project. The following sections decribe the approach taken to realize this objective and a brief description of the product.

Approach

The preparation for development of the training content and training strategies to be included in the Night Training Program (NTP) involved the meshing of multiple approaches. The training development expertise required for this work was drawn from research team members who are experienced in behavioral science applications to training development and/or knowledgeable about the critical aspects of night operations through prior military service.

A number of varied sources were utilized during this work. The literature review conducted by the research team during the first year problem analysis phase was a primary source for identification of tasks and useful training strategies. In particular, the literature pertaining to threat force analysis, the capabilities and limitations of STANO devices, and human performance under limited visibility conditions was re-examined (see Reference List).

A second source was the extensive review of USAIS mechanized infantry training that was conducted by the research team. The career courses for officers and noncommissioned officers were re-examined, with the focus on training blocks dealing with night operations content and practical exercises. Also, the reverse cycle portions of BIFV-specific courses were addressed particularly. Compilation of information from multiple resident courses helps isolation of effective training approaches for retention in the NTP to be developed, and ineffective practices to be avoided.

Contact with SMEs in the field regarding their perceived requirements for a night training NTP was a third important source of background information. Points of contact among the USAIS training cadre were consulted. The trip reports from the on-site visits to BIFV units in USAUR and CONUS, conducted by the research team during the problem analysis phase, were re-examined. Finally, the research team member principally responsible for POI development was an invited participant at a night operations workshop hosted by the Combined Arms Center, 12-13 March, 1985. Other attendees were representatives from the branch centers/schools who could speak for their respective commandant

concerning night operations doctrine. Each representative briefed his functional area, at the maneuver battalion/battalion task force level, in the following format:

- Planning and employment considerations;
- Functional area support of combat operations at night;
- Training considerations.

The workshop was planned and hosted by CAC for the purpose of obtaining input for the first draft of FC 90-1, Night Operations. The agenda afforded the ARI/Litton research team member with ample opportunity to exchange views on night operations doctrine and training with an Army-wide sample of SMEs. Training approaches of proven effectiveness, and innovative ideas capable of development and implementation, were incorporated in the development of the BIFV NTP.

These multiple sources were integrated in a comprehensive listing of the individual and collective tasks to be emphasized in a BIFV-specific NTP. These included activities which are required only when limited visibility conditions prevail, and daytime tasks which are particularly difficult or performed in a modified manner when natural or artificial obscurants limit visibility. Next, appropriate training strategies for the identified tasks were selected or developed (using lessons learned from the training community and innovative approaches formulated by the research team). The complete training program is in Graber, 1986; an overview is given in the following subsection.

The BIFV Night Training Program (NTP)

The ARI/Litton BIFV NTP follows a standard military format. An outline of the content and organization is presented below:

- PREFACE

  POI Description
  Training Notes

- BODY
- TRAINING ANNEXES

  STANO Devices
  Maintenance
  Weapons
  Gunnery
  Tactics
  Safety

- EQUIPMENT AND AMMUNITION SUMMARY
- CORRELATION OF TRAINING OBJECTIVES TO REFERENCES

- REFERENCES
- TRAINING GRID
- STANO DEVICE DISTRIBUTION

The intended audience for this unit training NTP is the platoon/squad level trainer. Therefore, the training notes directly address the needs and characteristics of this user group. The initial notes establish the importance of NTP, and the way to use it to organize and conduct maximally effective unit training in night fighting. Additional notes address general aspects of conducting night training and the potential distractors impacting upon the motivation and learning of the troops being trained under limited visibility conditions. Guidelines are given for innovative techniques to: (a) counteract training distractors; (b) overcome limitations in training resources and available training areas; and, (c) capitalize on available daytime training hours and indoor training environments to simulate the essential aspects of limited visibility conditions in the field.

The training annexes detail training objectives, conditions and standards for essential night fighting tasks. The information necessary for tailoring training content and sequencing to the needs of individual units is presented in these sections. Other sections list essential training references readily available in the units and correlate the training objectives to the appropriate reference(s). A training grid suggests appropriate calendars for annual schedules. Finally, all essential administative details for conducting effective unit training are treated in several sections.

The draft NTP was staffed with SMEs representing the U.S. Army Infantry Center/School and cadre of TO&E units. Revisions of content and organization in accordance with suggestions from this source were completed.

Conclusions and Recommendations

The ARI/Litton Night Training Program (NTP) is designed to fill the presently existing void in guidance to BIFV units for conducting limited visibility training. Unit trainers can draw immediate benefit from the contents of the NTP in its present form. Therefore it is recommended that:

- The present version of the Night Training Program be circulated among trainers in active BIFV units. Requests for Comment/Amplification/ Modification are essential to development of future, more detailed and specific training guidance.

Future work should be directed toward development of a second iteration of this NTP. Comments and suggestions from the field should be used to improve the initial version. Also, the recent training developments accomplished by the ARI/Litton research team during work in other areas reported upon here and in the companion report on gunnery procedures should be included in the second iteration. For example, the modified training in use of the thermal mode of

the ISU for target detection and range estimation could be inserted in an appropriate section of the initial NTP. Therefore it is recommended that:

- Future work be performed by an appropriate action agency to produce and evaluate an expanded Night Training Program that incorporates newly developed night fighting concepts, training devices, job aids and training strategies.

Through-the-Sight Video

Background

The phrase "through-the-sight video" denotes a relatively recent application of existing video and optical technology. When the device is integrated with the BIFV ISU, the optical display is seen simultaneously by the commander and gunner at their stations, and is also transmitted to a video camera/recorder. The image is not degraded at any of the three terminal points. In other words, the optical component of the system (the "beam splitter") provides a means of duplicating the exact sight picture to a remote video monitor and/or to video tape for permanent storage. The through-the-sight video (TSV) device shows promise in a number of training and research areas relating to BIFV gunnery, tactics and techniques.

The TSV was demonstrated at Fort Benning during the course of a gunnery training device Concept Evaluation Program test entitled "Gowen South." This exercise was conducted by the Infantry Board for the Directorate of Training and Doctrine, USAIS and a number of devices were investigated at that time. The TSV device was used as a research tool at that time, but it serendipitously demonstrated training potential. The BIFV research team determined that substantive work to develop this concept should be done and that purchase of a system would be necessary to facilitate ARI/Litton work in this area. In prototype form, the cost for the complete system is approximately $46,000, with the most expensive component being the beam splitter at $11,000 (a complete description of the system is presented below). The order was placed in January, 1985, but problems encountered by the manufacturer delayed delivery of a working prototype until August, 1985. This severely limited the opportunity to implement any systematic investigation within the remaining period of the current contract. However, the research team has accumulated experience with the operation and capabilities of the device and these preliminary results are reported here.

Description of the TSV System

The system consists of five components which accomplish the duplication of the ISU sight picture without any degradation of the ability of the commander and gunner to use the ISU in a normal manner.

Beam Splitter. The manufacturer (DBA Systems, Inc.) designates this component as the M2/M3 Light Beamsplitter. The beamsplitter is an optical mechanical device that is inserted into the ISU system in front of the Bradley Commanders Relay Assembly. It duplicates the optical transmission for presentation to the camera (see Figure 5). In order to duplicate the gunner's sight resolution at the edge of the field of view, the optics are designed to correct the field curvature for the flat image plane of the camera to provide high resolution over the full field of view. An adjustable iris is incorporated into the beamsplitter to manipulate the aperture for optimum camera exposure over varying scene illumination conditions. The system can deliver image plane resolution of 80 line pairs/mm.

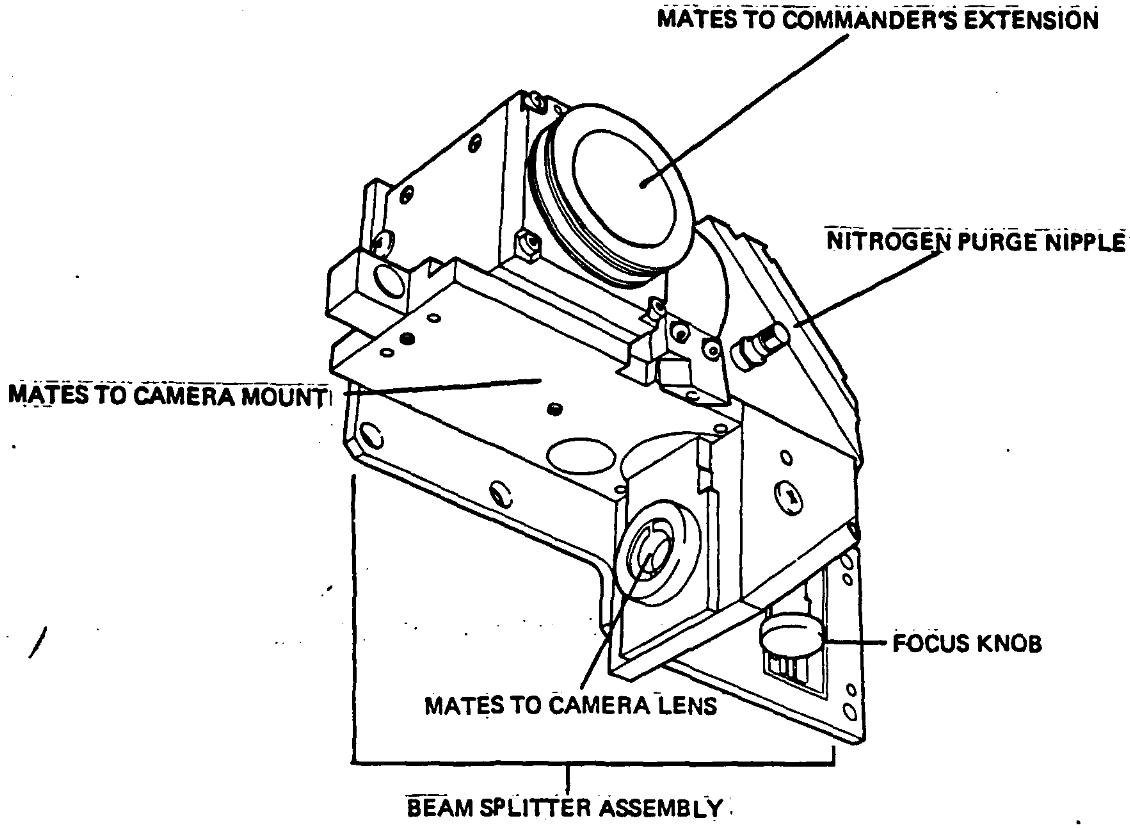


Figure 5. The TSV beam splitter.

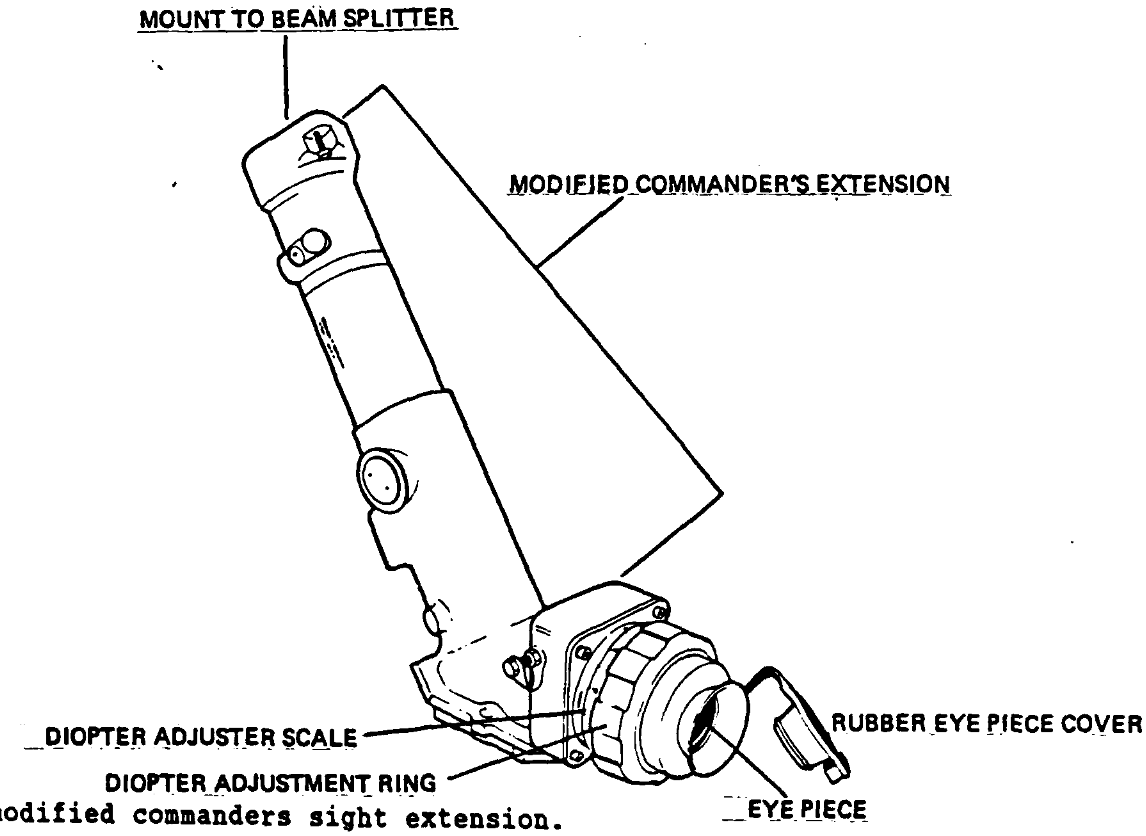


Figure 6. The modified commanders sight extension.

Modified Commanders Extension. The modified commanders sight extension is also supplied by DBA Systems, Inc. (see Figure 6). To install the system, the present commander's extension is disconnected from the ISU, the beam splitter is connected to the ISU, and the modified extension is connected to the beamsplitter. The modification is designed to accomodate the presence of the inserted beam splitter so that the position of the commanders extension eyepiece in the horizontal and vertical planes is not changed.

Camera. The video camera used in this prototype is supplied by GBC, Inc. (see Figure 7). The current model is a black and white camera. The camera is connected to the beamsplitter by insertion in a mount that is a part of the top of the beamsplitter. Cables connected at the rear of the camera carry the output to the monitor and the control module separately.

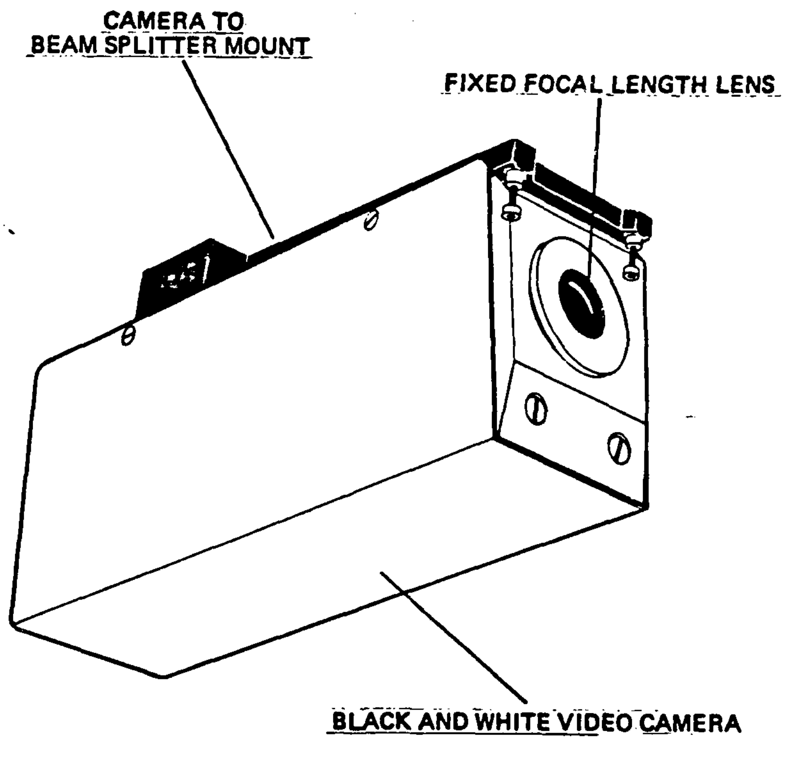


Figure 7. Video camera used in the TSV prototype.

Monitor. The monitor is manufactured by GBC, Inc., and supplied by DBA, Inc. It is black and white capable without audio capability and requires 28 volt DC power for operation.

Control Module. This multifunction component centralizes the video recording controls. (See Figure 8.) A time code generator (TCG) overlays date and running time on the monitor and the video tape. A VHS Format VCR providing 120/360 minute tape run time is incorporated in the module. The module receives 28 volt DC vehicle power, shunts it to the video monitor and steps down the 28 volt DC to 12 volt DC via two power regulators mounted in series. The 12 volt DC powers the camera, VCR, and TCG.

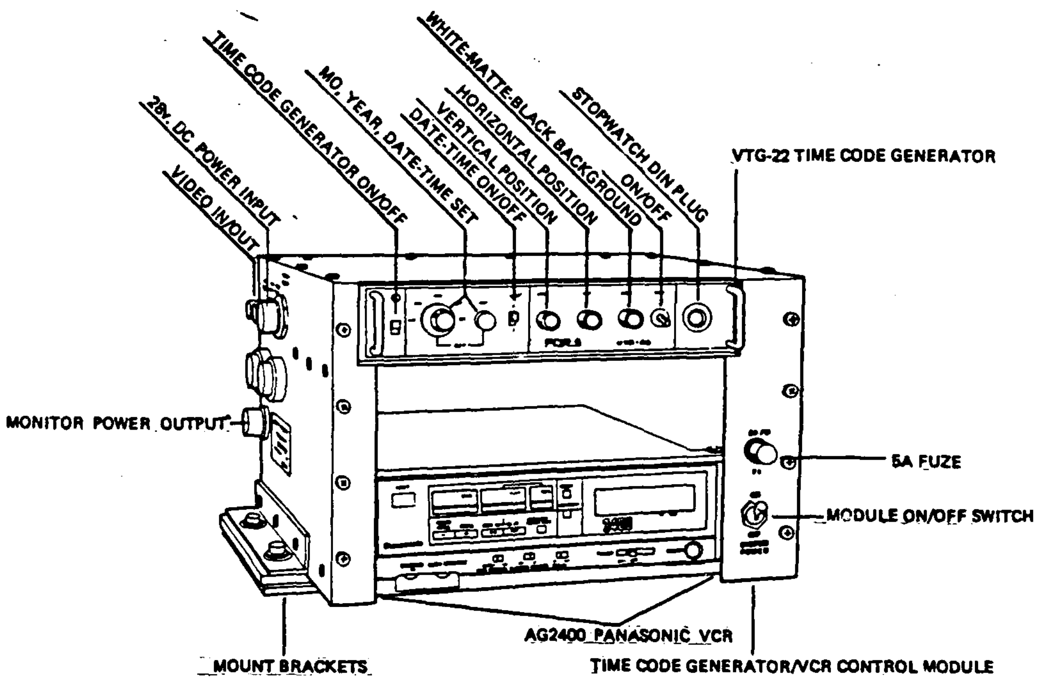


Figure 8. The TSV control module.

Applications

The research team developed a list of the major applications of the TSV device for immediate investigation and also noted potential "spin-off" uses for institutions, field units or basic research. The most important applications, of course, are those which show potential for solving some of the BIFV issues

which were identified during the problem analysis phase. These identified needs related positively to gunnery training and research to enhance the BIFV data base, as explained below.

Gunnery Training Applications. The subsection of this report titled "The Bradley Commander's Course," described a major bottleneck impacting upon BIFV training. A great deal of the training must occur in and around the turret of the vehicle, which has limited space for both a group of students and an instructor. Many of the training tasks are sensitive to both the instructor/student ratio and to the need for the instructor to see the sight picture simultaneously with the student as he performs. Also, the transitory nature of the sight picture information hampers effective instructor critique. A device enabling training cadre (and nonperforming students) to view the sight picture from a remote station during training would relieve the turret bottleneck. The capability to selectively store pre-screened sight pictures and sequences of events in real-time motion (with the associated audio record) would enhance the training flexibility available to cadre in several ways. It would permit the presentation of classroom type preperformance instruction to groups of students, using a sequence of previously obtained sight images ranging across a variety of visibility conditions and target arrays. Secondly, storage of actual training events would increase instructor ability to present meaningful critique. The sequence of enhanced group instruction, enabling the student to derive increased benefits from the current techniques of hands-on training, reinforced by a specifically tailored post-performance critique, would be a powerful modification of current institutional and unit training.

In particular, unit gunnery sustainment training could be expected to benefit in the following task areas:

- Aiming
- Zeroing
- Thermal control manipulation
- Thermal sight image interpretation
- Tracking
- Fire commands
- Range estimation/indexing
- Target selection/classification
- Move-out gunnery engagements

Properly implemented, the TSV concept will have almost unlimited potential for realistic institutional and unit training in gunnery, tactics and techniques.

Research Applications. Development of the TSV concept would have immediate favorable impact on current training. In addition, the device is potentially

useful as a tool for research of presently unresolved issues. Increasing the knowledge base for modifying/improving current gunnery procedures will have future application to training and combat performance. For example, baseline data is needed on the way variables such as battlefield obscurants, target type and range to the target affect the thermal image of the ISU. At present, the need to use actual sight images at a prepared range severely limits the scope and objectivity of research studies. A systematically produced and edited video tape obtained with the TSV could serve as the basis for a rigorously controlled study with large numbers of subjects.

Limited Feasibility Testing

As noted, late delivery of the prototype prevented implementation of a large-scale test plan within the scope of this project. It was possible, however, to capitalize on two field studies previously scheduled for Fall, 1985. These were the Span of Control field test (see Section 1) and the evaluation of improved training for thermal sight manipulation (see Section 3, above). Research personnel acquired experience in mounting the TSV in an operational BIFV and perfected techniques for operating the device in a real-world situation. The video tape products obtained support a number of conclusions.

Video tape obtained with the target scenarios used for evaluating the modified thermal training program demonstrate the versatility of the TSV device. The experimental tape has been viewed critically by the research team and SMEs at Fort Benning. Evaluations are unanimous that the images have high fidelity in both motion and still modes, across all variations of polarity, magnification, and brightness/contrast. Editing would support training in scanning techniques, appearance of thermal signatures, manipulation of thermal image controls to obtain the best picture, and other applications.

During the tactical exercise that was designed by the research team to investigate the leader span of control issue, the opportunity to further explore TSV in additional real-world situations was exploited. The TSV was mounted in a vehicle assigned to the friendly force. It was noted that the friendly force commander and gunner were not hampered in their combat performance by the presence of the TSV device in their BIFV. Video tape was obtained of a fluid battlefield situation as it appeared through the ISU, in contrast to the static range situation filmed earlier. Portions of the taping captured thermal images of enemy vehicles on the move before and during obscuration of the battlefield by smoke. Clear sequences of an attack helicopter during a simulated enemy air strike also were obtained. When the vehicle itself was moving, engagement of the gun stabilization system was sufficient to produce video tape of a quality comparable to the static situation.

The exploratory video tape products obtained suggest a number of possible applications in addition to use in gunnery training. For example, the terrain is depicted as seen by the Bradley gunner and commander through the daylight and thermal sight at high and low magnification. Through effective editing, such representations would provide a low-cost type of surrogate travel

experience for use in classroom settings. Terrain driving, route selection and land navigation are potential areas for training with this aid.

Finally, shortcomings of the device were logged during the activities described above. The prototype TSV was adequate to demonstrate the viability of the concept, but improvements could be made in selected system components. The beam splitter is sturdy and reliable, but addition of a mechanism to permit on-site adjustment of the fit, to accomodate differences in individual ISUs when mounting the device, could be developed at little additional cost. The cost and feasibility of exchanging the video camera used in the prototype should be investigated. There is a need for a model which offers: (a) color capability; (b) audio pick-up; (c) reduced size; (d) greater reliablility; (e) capability for radio-frequency signal transmission to a remoted monitor or recorder. The method of transmitting the video signal by cable used in the prototype TSV should be retained as an alternative system. However, techniques of arranging the cable array so that it does not become entangled during free turret operation must be developed. Finally, modifications permitting weather-proofing and space-saving design of the assembled system should be pursued.

Conclusions and Recommendations

Despite the delay in delivery of a TSV prototype, the research team was able to accumulate valuable experience with the concept by planning non-interfering satellite activities during the conduct of previously scheduled research in other areas. It was found that installation and operation of the device are compatible with the practical requirements of both training and research applications.

The monitor display and storage on tape obtained under realistic conditions, show dramatic promise for multiple applications. The discovered shortcomings of the present prototype device were analyzed and it was found that reasonable recommendations for viable modifications could be made in each case. Therefore, future work should be planned and implemented to further develop the concept for BIFV specific training.

Specifically, it is recommended that:

- The prototype TSV be used in future work to develop procedures, lesson plans and audio-visual materials for gunnery training applications;

- The prototype TSV be used in future work to develop applications in tactics and techniques for BIFV small unit leaders;

- The prototype TSV be used in future research to expand the data base relating to BIFV ISU thermal imagery;

- The prototype TSV be used in future research to develop and validate improved gunnery procedures and techniques;

- **Work be undertaken to upgrade the prototype TSV to produce an operational version applicable for to use in a wide variety of institutional and unit settings; modifications should be designed to provide for weatherproofing, ruggedness, compactness, and simplified installation.**

Scaled Vehicles And Ranges

Problem Definition

The ARI/Litton research team observed BIFV units during the conduct of ARTEPs, at sites in both USAEUR and CONUS, as a part of the problem analysis phase of this project. These unit exercises were conducted at major training areas (MTAs) specifically dedicated to such training and unit evaluation activities. The observers noted instances where individual or collective performance of tasks was less than optimum. Further investigation into contributing causes for performance shortfalls surfaced the issue of sustainment training at the unit home station for a large number of tasks. That is, the present home station environment may not support effective sustainment training because trainers are limited by the lack of suitable maneuver areas, full-scale ranges of varying types, or inadequacy of miniaturized simulations/training devices.

A prime example of this is the group of tasks related to engagement of the enemy with the technologically advanced firepower available to the BIFV crew. Current BIFV home station conditions do not support effective sustainment training in the areas of processing battlefield data on the immediate threat (individual equipment and tactical arrays), selecting high priority targets, and engaging the enemy with gunnery techniques that deliver all the lethality of the Bradley. The current difficulties encountered by unit trainers are particularly acute for conducting training of tasks that must be performed under limited visibility conditions.

Historically, home station training in these areas has consisted of exportable training packages based upon simplistic training technology such as static miniature vehicles on ranges at the same scale (1/35th scale or less). Presently available unit training aids for gunnery lack realism and do not permit sustainment training of whole tasks or integration of separately trained part tasks.

In particular, home station sustainment training of night BIFV gunnery, an especially perishable skill, is not supported by available training strategies and training aids. Small scale models are not only static but also "cold," producing no realistic thermal cues. Available exportable packages such as videotape and slide presentations of friendly and enemy vehicles in varying visibility conditions are reasonable approaches, but have limited flexibility in the range of part-tasks that can be addressed with such a training strategy. Training of whole tasks such as the critical process of interaction/communication between BIFV commander and gunner during night engagement of multiple, moving targets is extremely difficult for managers of home station sustainment training.

Sophisticated computor-managed gunnery simulators are within the state of the art and could theoretically support training scenarios that realistically simulate a threat battlefield array under limited visibility conditions, complete with technology that supports student practice of tactical gunnery.

However, these developments are still in the infancy stage, and the future availability of such training devices for home station sustainment training is an open question.

An alternative solution that has been recognized for a number of years is to train gunnery and tactical tasks using scale ranges, with and without small caliber ammunition. Efforts to implement scale ranges with mobile, reactive, radio controlled targets has been hampered because scale tank targets have required frequent recharging of heavy batteries for electrically driven vehicles. Radio-controlled aircraft have been used for training air defense gunnery, but the development of scale tanks has not progressed beyond the heavy, unreliable battery-powered vehicles.

Technological advances have brought more sophisticated approaches to BIFV home station sustainment training within reach. It is appropriate to re-examine the scale target/scale range training strategy because;

- Self-propelled vehicular models produced at 1/8th scale are now available on an off-the-shelf basis;

- Remote control of single vehicles and tactical arrays of multiple vehicles is well within current state-of-the-art;

- Efficient and cost effective visual modification of the model shell to simulate a wide range of vehicles is a potential feature within the reach of current technology;

- Technologies for indicating target hit/miss are available;

- Utilization of the scale model in conjunction with a 1/8th scale range would require an area 300 meters square in the vicinity of the unit's home station.

Properly developed and integrated, the technological advances listed above would meet multiple training requirements over a range of training applications. This section describes work performed by the ARI/Litton research team to explore the potential of this conceptual approach for multiple training applications, day and night.

Approach

Training Requirements. The research team compiled a list of the major training requirements for a training aid to be used in BIFV home station sustainment training. In order to constitute an advance over currently available training approaches, the concept outlined above will have to meet these requirements.

Realism. The model must be capable of presenting a high fidelity reproduction of selected threat or friendly vehicles. The cues presented to the student by the model should replicate essential aspects of vehicle signatures (exhaust, radar, thermal, and visual appearance.) Additionally, the model must be capable of reacting realistically to student actions.

Therefore, it must be able to maneuver/evade cross country and provide accurate gunnery feedback. The criterion of realism would have to be satisfied as completely for night training as for performance of tasks in daylight.

Universality. The targets must be suitable for the entire range of weapons mounted on the BIFV or carried by the dismount element. Therefore, the cues presented to the student by the scale models through both the day and night sights of the weapon systems must include all the essential information. The targets must be modifiable to represent a wide range of enemy and friendly vehicles.

Flexibility. The training aid should support practice in both single target engagement and tactical gunnery to cope with target arrays. In conjunction with a scale range, the model must support a wide range of day and night scenarios.

Timeliness. The training concept must be responsive to the Army training 1990 goal of Simulation, Substitution and Miniaturization (SSM)

Training Applications. The major BIFV training applications which would be supported by this training concept were identified by the research team. These fall into the areas of gunnery, command and control and tactics. The items cited below represent examples only of the wide range of applications that would be available to imaginative training managers.

- Gunnery
  - "Backyard" dry fire practice, daytime and limited visibility
  - Optical/thermal target detection/identification
  - Multiple moving target engagement
  - Combined arms target prioritization
- Command and Control
  - Preparing section/platoon defensive fire plan
  - Directing section/platoon fires from defense
  - Call-in indirect fire
  - Tactical force-on-force exercises
- Tactical Training
  - Selecting firing positions
  - Implementing obstacle plan/breeching obstacles
  - Military Operations on Urban Terrain (MOUT) techniques
  - Force-on-force scenarios--squad through company level

The applications listed above are only suggestive of the wide range of training objectives that the training concept is suitable for, when utilized by imaginative trainers. Figure 9 shows one possible training scenario that could be created with remote controlled scale vehicles on a scale range.

This figure shows a BIFV platoon on-line facing realistic terrain and an array of enemy vehicles in varying postures. Individual skill training for BIFV gunners in the areas of maximizing the sight picture, engaging moving targets with proper lead and lag rules, and estimating target range (for

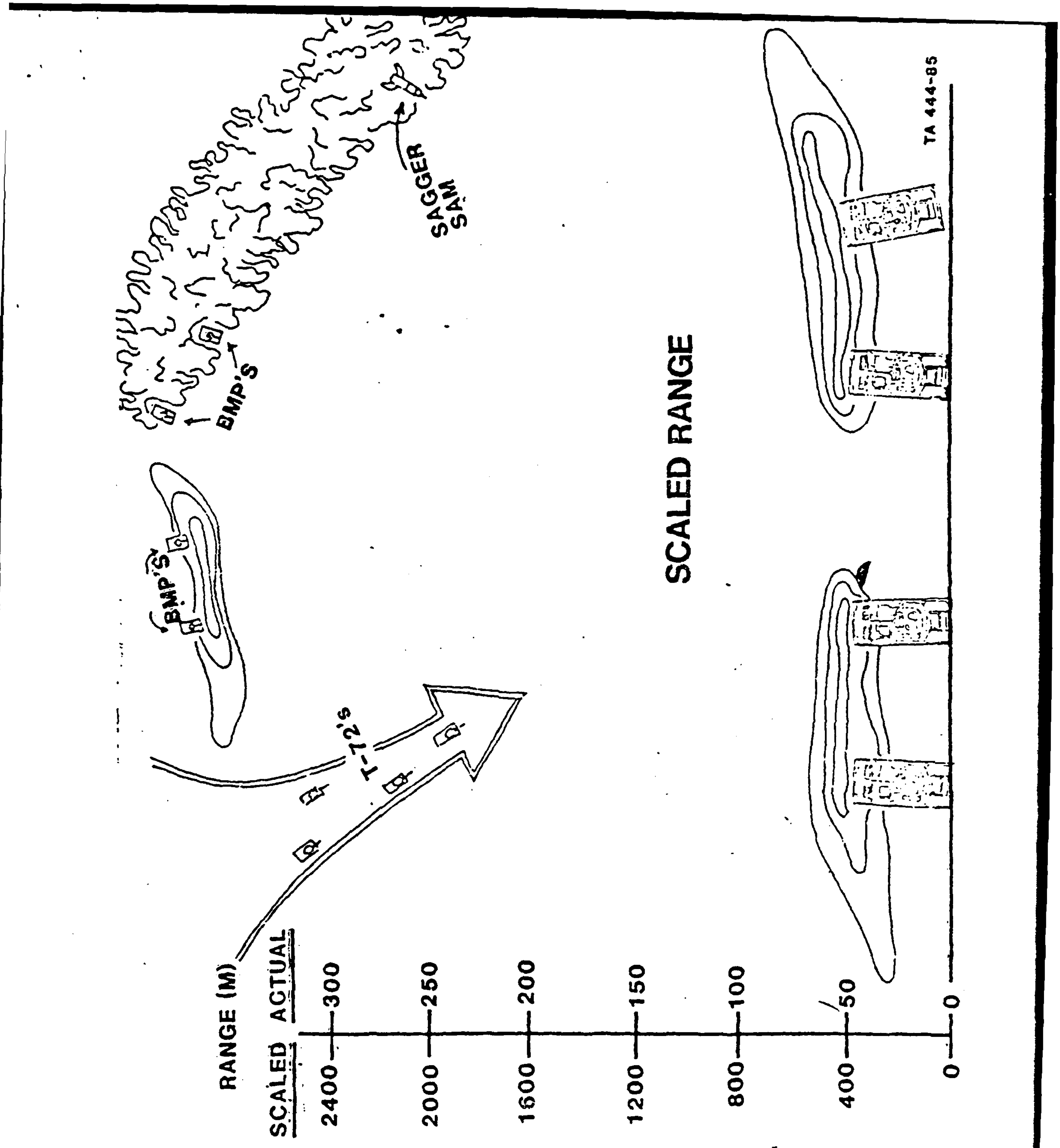


Figure 9. Scaled vehicle/range training concept.

example) could be conducted effectively with this training scenario. Practice of crew tasks such as the required interactions between commander and gunner, or between commander and driver is a second type of training supported by this approach. Finally, collective tasks such as squad/platoon/company tactical operations could be realistically simulated. There are no obvious limitations to the production and employment of additional realistic scenarios for stationary or moving targets, singly or in arrays, under the full range of visibility conditions.

Concept Development. Three 1/8th scale vehicles were delivered to ARI, Fort Benning Field Unit, by the Training and Technology Agency (TTA), TRADOC, with the request that feasibility testing for training applications be conducted. These vehicles are off-the-shelf products manufactured by a Japanese firm for the model enthusiast market. The visual appearance of this particular model is a detailed representation of the Japanese Defense Force Type 61 tank. The construction includes a hull of welded sheet steel, a turret of cast aluminum, and steel tracks and running gear. The dimensions of the model at 1/8th scale are: (a) weight, 110 lbs; (b) height to top of the cupola, 13 inches; (c) overall length, 30 inches; (d) width, 15 inches. (See Figure 10.)

The models were delivered with operational turret traverse and cross-country automotive systems. Several additions to the models were made to add radio remote control capability and a gunnery feedback system so that a complete prototype of the training concept would be available for feasibility testing.

Radio Remote Control. A local vendor was contracted to supply a four-channel radio remote control system for each target vehicle. Receivers on each copy of the product can be set to respond to an individual radio frequency, allowing independent operation of several models simultaneously. The controller station utilizes a typical joystick arrangement. Figure 10 below, shows an illustration of the controller station.

Lateral motion of the right stick controls engine throttle, with full left giving maximum throttle and full right producing shut-off of the vehicle. Gun turret rotation is controlled by the lateral motion of the left stick. Forward or reverse motion of the right stick produces corresponding motion of the right track, and the left stick controls the left track. The further the sticks are displaced, the faster the track moves (proportional control). Directional steering is accomplished with differential inputs on the two sticks. The vehicle will steer to the left or right by returning the corresponding stick toward the neutral position. A center line pivot steer can be accomplished by reversing one track while running the other forward, enabling the vehicle to turn within its circumference as with a full scale vehicle pivot steer. Results of tests of the control system are reported below.

Multiple Integrated Laser Engagement System (MILES). Several technologies were explored to determine the one most appropriate with these scale models as a training concept. Frangible ammunition was rejected because the muzzle velocity of 5300 feet per second will damage the scale model at the distances that would be used on scale ranges. The maximum range of the ammunition is 250 meters which, again, is not suitable for a scale range with 300m depth.

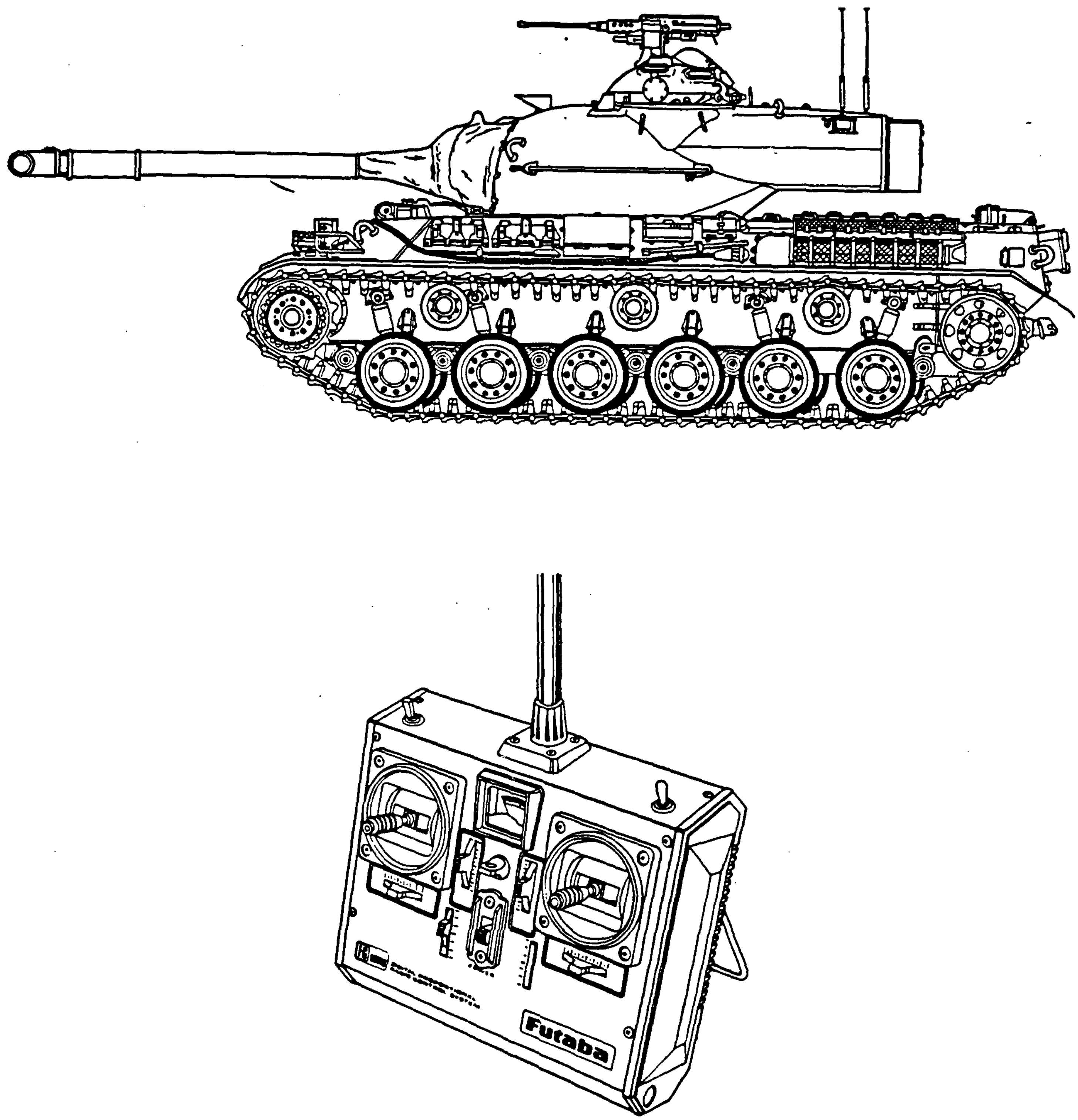


Figure 10. Model vehicle at 1/8th scale and remote control station.

Additionally, it would be necessary to cease fire and assess round impact down range after each trial. Compressed talcum ammunition does give a visual indicator of round impact with a small puff of talc smoke. However, it was estimated that the impact point of a 5.56mm talc round could be seen only at very close ranges with the ISU in high-magnification. The round could penetrate the skin of the scale model, creating the same maintainance and cost problems as with frangible ammunition. The MILES type of target kill identifier was identified as the approach offering the most potential, from the following perspectives:

- No damage to the target vehicle;
- No requirement to procure special ammunition;
- MILES systems already exist for the Bradley;
- MILES could be employed with the BIFV 25mm gun, TOW and DRAGON weapon systems;
- MILES can supply information on near misses and also simulate catastrophic kills with activation of engine shut-down.

A contract with Simulaser Corporation was intitiated to produce a MILES system for the scale model according to ARI specifications. Four detectors were installed at strategic points around the model tank turret. Laser pulses impacting on any detector activate the amplifier and decoder which is also mounted on the turret. For one of the model vehicles, a buzzer and flasher provide an audio visual signal of what has occurred. Upon detecting a kill, the buzzer sounds for approximately 15 seconds and the strobe flashes 12 to 13 times. The signal for a near miss is three intermittent beeps of 1 second each and a strobe flash of 2 to 3 times. For the second model, the audio signal is identical, but the visual signal of a light is substituted for by activation of a smoke cartridge on the tank.

The flasher and smoke visual signals are not considered the optimum feedback mode for purposes of realism; light and smoke are possible distractors during night training and the model would not automatically halt its momentum in realistic simulation of a kill. A system whereby detection of a kill by MILES would initiate an engine shut-down is preferable. The work performed by Simulaser will support future development of this feature and feasibility testing of the target kill identification system can proceed with the present visual cues. The final report of contract work appears in Morey, 1985. Results of testing of the delivered system are reported below.

Results of Limited Feasibility Testing

The off-the-shelf model was subjected to some exploratory testing using local terrain and training areas. Information was obtained on the performance of the radio remote control system, the MILES feedback system, and the engine and drive train of the model. Also, information on the appearance of the model through the integrated sight unit (ISU) in daylight and thermal modes was obtained. Details are presented below.

Adequacy of the Control System. The control system was exercised by several members of the research staff over varying local terrain. The controls were found to be simple to master and were responsive and reliable over the

entire range of movements desired of the training aid. Problems with vehicle movement discovered at that time were traceable to inadequacies in the propulsion system (see subsection treating this subject below) rather than the radio remote control system.

Adequacy of the MILES System. The MILES detection system mounted on the scale vehicles was exercised using a Tripod Mounted TOW equipped with MILES and a MILES controller gun. A 10-power rifle scope was used to establish the aim point of the controller gun and data was accumulated on the reaction of the vehicular mounted MILES equipment for differing aim points. This preliminary data indicated that the installed system discriminated reliably between near misses and hits and gave no false positives. Further work would be necessary to establish the exact MILES envelopes for the near miss and catastrophic kill, for the scale target used with MILES equipped BIFV weapons. The Tripod Mounted TOW used in this exploration was bore-sighted for 3000 meters and this resulted in parallax problems at the short ranges involved. Input from Subject Matter Experts indicates that appropriate calibration of the beam and optics can reduce this problem across the range of BIFV weapons.

Adequacy of Appearance Through Day/Thermal Modes of the ISU. The scale vehicle was transported to a local BIFV range and placed at an appropriate distance down range. Members of the research staff and SMEs viewed the model using the BIFV ISU during daylight and using the thermal mode during hours of darkness. The actual sight picture was judged to be highly realistic across the range of sight magnification and mode. Video tape obtained at the time was also subjected to scrutiny and the results were satisfactory. It was noted that inadvertent inclusion of a familiar full-scale object within the sight picture destroys the realism for the viewer. Therefore, attention to selecting an appropriate ecological surround is critical; a high fidelity simulation of full scale movement through areas of small trees, across washes and breeching obstacles can be produced with a minmum of preparation.

Adequacy of the Propulsion System. In order to meet the projected training requirements, the scale vehicle must be able to operate on ranges that simulate (to scale), the variety of soil conditions, vegetation, and slopes/obstacles that a full-scale enemy vehicle can negotiate. Speeds over broken terrain must also be appropriate to the scale simulation; i.e., the vehicle should be capable of speeds continuously variable from full stop to a maximum in the 4.5 mph range.

The prototype model was exercised under selected conditions that presented these types of challenges. Several deficiencies in the propulsion system were found. These deficiencies were noted and analyzed. Excessive difficulty in negotiating uncut grass (2-3 inches high) occurred consistently. Turns on smooth surfaces which would simulate the evasive maneuvers of a full scale enemy vehicle were especially unsatisfactory in the existing system.

The model is powered by a two-cycle gasoline engine through a centrifugal clutch to a gear box. Servo-driven clutches engage each track independently. The field tests indicated that the gears and clutches are prone to excessive wear and require frequent adjustment. Overall, the drive train appeared to have a number of poorly engineered parts that could not support continued use of the tanks in a realistic Army training environment.

These deficiencies of the propulsion system (and others detailed in Annex 9) indicated that the specifications of the off-the-shelf model would have to be modified to meet the projected training requirements. Because the tanks are otherwise ruggedly built and could provide a variety of training opportunities not currently supported by other training systems, development of an improved drive train was considered an immediate and feasible goal. The following subsection describes work performed to upgrade the prototype model.

Improvements to the Propulsion System

Engineering Studies Performed by Georgia Tech Research Institute. The results of the exploratory testing were considered highly promising. It was determined that further development work to produce needed improvements in the vehicle propulsion system could be undertaken at a reasonable cost. A contract was initiated with Georgia Tech Research Institute (GTRI) to conduct further engineering studies of the original engine, transmission, and suspension system, to fabricate and install improvements on one scale vehicle, and to recommend additional improvements that would increase the suitability of the prototype as a training aid.

Completed Modifications. Studies by GTRI determined that the established deficiencies in the mobility performance of the original vehicle centered on the transmission. Several options to the original all-mechanical approach were analyzed and a hydrostatic solution was adopted. The required modifications to the original drive train were fabricated, installed on a vehicle and submitted to performance tests. The original engine was replaced by a 3.9 horsepower engine with upgraded performance to support additional development of the hydrostatic drive train or reconsideration of other drive train configurations. Indications are that the modified engine/drive train can deliver the power required to propel the vehicle at speeds up to 4.5 mph up a 30 percent incline.

Upon completion of the contract GTRI delivered to ARI the modified vehicle and a report detailing the work performed and recommendations for improvements to further fine-tune performance of the scale vehicle. The report is available as an appendix to Morey, et al., 1986.

Future Development of the Propulsion System. The modifications to the major components of the propulsion system have had the effect of increasing the trafficability of the vehicle. Future work should be directed at upgrading supporting systems in the areas identified jointly by GTRI and ARI. Specific engineering improvements are listed in the recommendation section which follows.

Conclusions and Recommendations

A training concept based on the utilization of a remote controlled, 1/8th scale, target vehicle in conjunction with a scale range was explored by the approach described in this section. An off-the-shelf model was subjected to limited feasiblity testing, to determine the potential for satisfying the identified requirements of a training aid to be used particularly in BIFV unit home station sustainment training. The results indicate that, while

deficiencies still exist, the concept has potential for development and delivery, not only to units but also to resident courses in the institutions and to Reserve/National Guard training environments. Further work to elaborate the concept should be conducted. Specifically, it is recommended that:

- Engineering improvements be made in the model as presently modified. Identified areas for improved design and fabrication are:

  (1) Reduction of heat build-up by increasing space within the hull (for more adequate airflow);

  (2) Reduction of vibration within the hull;

  (3) Increased responsiveness of the suspension system;

  (4) Consolidation of on-board electrical generation with increased capacity for operating training peripherals;

  (5) Ruggedization of the chassis, tracks and suspension systems;

  (6) Addition of two radio channels to support a remote start/restart capability;

  (7) Elimination of radio intererence (RFI) produced by the modified engine system;

  (8) Addition of an engine shut-down feature activated by the MILES system upon detection of a catastrophic kill;

- Capability to fabricate shells replicating major threat vehicles be developed and simple procedures for exchanging shells in the field training environment be established;

- Alternative approaches to gang-control of multiple models be identified and subjected to feasibility testing;

- A prototype training program utilizing the scale vehicle/range concept be developed and evaluated in a training environment approximating home station sustainment training;

- Prototype training support materials for the scale vehicle/range concept be developed to include, at a minimum, sample scenarios/lesson plans, instructor's guide, and operating manual(s).

SUMMARY

The ARI/Litton Bradley Infantry Fighting Vehicle Project was initiated in the Fall of 1983. The contractual scope of work defined the tasks to be accomplished within the time frame of September, 1983 to December, 1985. Additional guidance and focus was given to the project by the content of a Memorandum of Understanding subscribed to by: (a) the Director of the Training Technology Activity, Office of the Deputy Chief of Staff for Training, U.S. Army Training and Doctrine Command; (b) the Assistant Commandant of the U.S. Army Infantry School; and, (c) the Commander of the U.S. Army Research Institute. The unifying focus of the charter given to the ARI/Litton research team was the requirement to emphasize the special aspects of BIFV operations conducted at night and during daytime limited visibility situations.

The overall project was divided into two phases of approximately one year duration for each phase. The objective of the first phase was to conduct a broad-base analysis of BIFV doctrine, equipment and training (with special emphasis on limited visibility operations). The initial dedication of effort to exploration and "problem identification" was a highly logical start point, in light of the fact that the newly-fielded Bradley weapon system represented a sophisticated intregration of technologically advanced equipment that made new concepts for the Infantry role in combined arms operations possible. In other words, the wide-ranging versatility of the Bradley was both a boon and a challenge to the Infantry to refine equipment configurations, create employment concepts and develop training programs for BIFV leaders and crew.

Though the problem analysis was initiated by the research team in accordance with the guidance to focus on BIFV issues specific to night and limited visibility operations, the emerging results of the problem analysis indicated very early that it would be necessary to broaden the investigation to address basic tenets for BIFV training, equipment and operational employment that cut across both day and night fighting. For example, the question of what are the limits for small unit leader span of control surfaced as an issue of concern within the BIFV community. However, whether the typical BIFV platoon leader can exercise effective control without task overload, given the many new duties created by the nature of the Bradley weapon system, could not be answered logically for night operations without prior investigation of the situation for daylight conditions. Therefore, though the emphasis upon night and limited visibility conditions specified by the charter was observed, additional basic issues which are not condition-specific were explored.

Upon completion of the problem analysis phase, the research team documented over 100 separate deficiencies, that had been identified through a multi-disciplinary approach to investigating the then current BIFV doctrine, equipment and training. However, it is potentially misleading to focus on the sheer quantity of the issues which surfaced. The overriding conclusion of the research team was that the new Bradley system was fundamentally sound and an appropriate answer to many of the requirements of the Infantry role in the Army 21 concept. The deficiencies were identified in the spirit of "making a good

thing better," and the research team found it possible to recommend high-feasibility solutions for each separate deficiency. Also, logical action agencies could be identified for each recommended solution.

A further general conclusion was that the staff officers, instructors and field commanders directly involved with the fielding of this revolutionary mode of infantry warfare exercised an exceptional amount of inititative and judgement to meet the highest priority issues first. The dramatic growth of a training, doctrinal and operational guidance program which the research team has witnessed during this project is due in large part to the efforts of these pioneers. The majority of action items which were presented at the completion of the problem analysis phase have since been implemented by the user/proponent, working either independently, or in collaboration with other agencies such as ARI.

Full details of the results of the first-year effort are available in two previously released documents of the series (see Bibliography). The present report documents the follow-on accomplishments of the second-year work on the project.

For the second phase of the project, the contractual scope of work specified an experimentation and test effort, building upon the initial problem analysis. From the total number of issues identified in the first year, ARI in conjuction with the Infantry School nominated a number of major areas as meriting further study or test by the ARI/Litton research team. These subjects were screened to emphasize research related to the night/limited visibility environment. Also, some subject areas which are not condition-specific were included because of their general importance to the combat effectiveness of the BIFV.

Synopsis of Results

Sections 2-4, and the associated annexes of this report, document the accomplishments of year-two BIFV project work in the areas of tactics and techniques, equipment and training. For each subject area, the problem has been defined, the approach to development of a solution(s) is described, supported conclusions are specified and directions for future work are recommended. A very condensed synopsis of the major conclusions and recommendations is presented (by subject area) here.

Platoon/Squad Leader Span of Control

A field exercise was designed to establish the environment necessary to produce the tactical conditions under which measurement of platoon/squad leader span of control was possible. The information recorded by the team of observers and the chief controller support the conclusion that there was no specific area of measurement in which leader performance errors could be attributed directly to fatigue, stress or preoccupation with other critical tasks. Failures of omission or commission appeared to be reflective of knowledge deficiencies or memory failure, not of lack of time or crisis-invoked situations. Therefore, current duties assigned to BIFV squad and platoon

leaders are considered to be well within their capability and capacity. However, leader performance can be improved through a job aid such as a functional Combat Leader's Guide, designed to provide a "checklist" formatting of leader duties by subject area, and through development of simplified tactical training scenarios.

Based upon the data acquired during the course of research into the issue of leader span of control, recommendations were presesented for improvement in leader training. These recommendations included development of a Combat Leader's Guide for use by BIFV squad and platoon leaders and creation of BIFV tactical exercises without troops (TEWTs) for use in instruction of BIFV leaders.

Continuous Operations

Based upon the analysis of the Threat and the emerging role of the Bradley in combined arms operations, the research team determined that there is a clear need for increased BIFV unit awareness of the combat-relevant aspects of continuous operations. This need must be met by providing small unit leaders with appropriate tools for preparing to survive and fight under conditions of prolonged operations. One of these tools is a Continuous Operations (CONOPS) Annex To Company Tactical Standing Operating Procedure, proposed by ARI/Litton. This SOP provides guidance suitable for establishing a routine work/rest schedule that units can use immediately to improve sleep discipline.

Placing guidelines for the conduct of continuous operations in the hands of leaders at company/platoon/squad levels will increase awareness of the issue and provide a tool for immediate use. Therefore, the ARI/Litton Continuous Operations SOP should be disseminated to BIFV unit commanders and trainers, with follow-up work planned to accumulate field comments and experiences with implementation of the SOP. Further, BIFV ARTEPS should be modified to permit evaluation of implementation of sound continuous operations procedures and penalization of individuals and units that fail to conform.

Ammunition Handling/Storage Equipment and Procedures

Reload of the 25mm gun must be performed in the minimum possible time because neither the 25mm gun, the coaxial machinegun, nor the TOW weapon systems can be employed while the turret is traversed to the reload position. Any reduction in the average time required by crews to complete the reload procedure will impact significantly on the survivability of the individual vehicle and squad, and upon the contribution of that vehicle to successful completion of the unit mission. Similarly, reload of the coaxial machinegun is a critical combat task that must be performed in minimum time. Modifications to the reload equipment for these two weapon systems were designed by ARI/Litton and prototypes were fabricated for testing.

Results of the evaluation procedures indicate clearly that the proposed modifications to the ready box and ammunition storage containers simplify the system configuration in ways that reduce the time requirements imposed by the system itself, permit the completion of the task by fewer individuals, reduce

the reload task training requirements, and increase the number of rounds that can be loaded in the 25mm and 7.62mm ready boxes.

The utility and feasiblity of the ARI/Litton modifications to the 25mm and 7.62mm reload systems were supported by the field evaluation conducted by the research team and by subsequent testing conducted by the Bradley Project Managers Office in conjunction with the prime contractor. Final determination should be expedited in order to make officially validated modifications available to BIFV units as soon as possible.

Troop Compartment Visibility

The present configuration of vision blocks (periscopes) does not support adequate performance of combat tasks by personnel within the BIFV troop compartment. These combat tasks include maintenance of close-in local security, performance of FO tasks, passive air defense and reconnaissance of the battlefield prior to dismount. Further, the confining aspect of the troop compartment contributes to incidence of motion sickness and feelings akin to claustrophobia. The ARI/Litton research team selected the concept of a transparent cargo hatch cover as a viable solution to these issues. A prototype was subjected to limited feasiblity testing and the results support the conclusions that effective performance of combat tasks from the troop compartment is facilitated by the transparent cargo hatch cover and troop compartment personnel react positively to replacement of the present cover with the modified cover.

The limited feasibility trial demonstrated that the prototype transparent cargo hatch cover is a promising concept. The research team also identified directions for further work to refine the concept; to include a two-man bench seat for use with the cover, an interior cover with Velcro fasteners to provide for proper light discipline, and procedures for reducing light reflection to minimal levels. The improved transparent cargo hatch cover should be subjected to a complete operational test. Further, systematic studies should be conducted to compare advantages/disadvantages of the modified cover to the present cargo hatch cover in the areas of performance of passive airguard, forward observer and local security tasks. Finally, systematic studies should be conducted to determine the degree of user acceptance of the transparent cover.

Thermal Mode of the Bradley Inte[illegible]ted Sight Unit

Comments from BIFV personnel in the field indicated that users perceive that the thermal mode of the integrated sight unit has inherent equipment limitations which restrict its utility. Hands-on experience acquired by the research team supported the conclusion that, despite some acknowledged deficiencies in human factors design of the sight and its controls, improved training in operation of the thermal mode could overcome many of the difficulties encountered by users. A training strategy and training materials for instruction in use of the thermal sight were developed. The prototype training approach was evaluated by comparison of the performance of novice personnel, after receiving the modified training, with an experienced group of

BIFV gunners trained under current approaches. The results of the comparison support the conclusion that a training solution can be developed and refined that will markedly improve the ability of unit personnel to use the ISU thermal mode to perform required tasks.

The results of the field evaluation of the proposed ARI/Litton thermal training program also establish the directions for further training development. The program should be revised to add practical exercises on scanning techniques, instructional procedures to insure use of the range card for every target range estimation trial, and procedures for using three ARI/Litton special texts that treat construction of a range card, thermal scanning techniques, and manipulation of the thermal sight controls. The revised training package should be tested at selected institutional and unit training sites, to include the Bradley Gunner and Commanders Courses, the 1st BN, 29th Infantry Regiment and several company level BIFV tactical units.

Basic research should be conducted to increase the information base specific to the BIFV thermal mode of the ISU--including but not limited to investigation of the effects on the ISU thermal image of important variables such as magnification and polarity combinations, range to the target, target cover, camouflage and concealment, and the impact of obscurants and weather variables such as fog, rain and snow. Other research efforts should be directed at development of an improved squad and platoon surveillance plan. An expanded and fully exportable training program should be developed, incorporating the results of the additional work.

The Bradley Commanders Course

Detailed analysis of the Bradley Commanders Course supported the conclusion that the overall quality of the course is very high considering its scope and the relatively short period since its inception. However, the ARI/Litton research team did identify a number of areas where constructive interventions would have high payoff potential. These fell generally into the areas of changes or augmentations to course content, course administration, and student evaluation practices.

The course review resulted in development of methods to improve the overall quality of the instruction received by students being trained as Bradley commanders. The maximum class size should be 30 individuals. The live fire annex of the POI should be revised to reflect accurate description of both the live fire and concurrent training objectives. A BIFV tactics test (with a passing grade required for graduation) should be administered and the tactics portion of the instruction should be augmented by use of guest speakers who are knowledgeable about critical BIFV operational issues. Finally, certain blocks of instructional content (particularly in the areas of tactics and gunnery), that could be added to the course without increasing course length, were identified.

Training for Night/Limited Visibility Operations

Although training directives dictate that one-third of all tactical training be conducted under limited visibility conditions, examination of current BIFV unit training schedules indicated that this was not being done for a variety of reasons. Field personnel queried by research team members indicated that the conduct of training specific to limited visibility conditions is hampered by the lack of adequate guidance on the optimal content and methods for such training. Therefore, the preparation of an up-to-date program of instruction for night operations training was identified as a high payoff area to be pursued by the ARI/Litton research team.

The research team developed a proposed Night Training Program (NTP) to fill the presently existing void in guidance to BIFV units for conducting limited visibility training. Unit trainers can draw immediate benefit from implementation of the NTP. The Night Training Program should be disseminated immediately to active BIFV units. Requests for comment, amplification, or modification are essential to the future development of more detailed and specific training guidance.

Through-the-Sight Video

The phrase "through-the-sight video" (TSV) denotes a relatively recent application of existing video and optical technology. When the device is attached to the BIFV ISU, the optical display that is seen simultaneously by the gunner and commander is transmitted also to a video camera/recorder. This provides a means for duplicating the exact sight picture to a remote video monitor and/or to video tape for permanent storage. The ARI/Litton research team explored the capabilities of the device in field settings and concluded that it shows promise in a number of training and research areas related to BIFV gunnery, tactics and techniques.

Future work should be planned and implemented to further develop the TSV device for BIFV-specific training. The prototype TSV should be used in future research to develop procedures, lesson plans and audio-visual materials for gunnery training applications and applications related to tactics and techniques for BIFV small unit leaders. The prototype TSV also should be used in future research to expand the information base relating to BIFV thermal imagery. Finally, work should be undertaken to upgrade the prototype TSV to produce an operational version susceptible to use in a wide variety of institutional and unit settings; modifications also are needed to provide for weather proofing, ruggedness, compactness, and simplified installation.

Scale Vehicles and Ranges

Technological advances have brought more sophisticated approaches to BIFV home station sustainment training within reach. It is appropriate to reexamine the scale target/scale range training strategy because self-propelled vehicular models produced at 1/8th scale are now available on an off-the-shelf basis, remote control of single vehicles and tactical arrays of multiple vehicles is well within current state-of-the-art, and technologies for indicating target

hit/miss are available for use with a scale model. Utilization of the scale model in conjunction with a 1/8th scale range would require an area only 300 meters square in the vicinity of a unit home station. Properly developed and implemented, the technological advances listed above would meet multiple training requirements over a range of training applications.

Future Scope of Work for the ARI/Litton BIFV Project

The summary, above, both describes project accomplishments and indicates directions for further work. Implementation of solutions presented here will have a beneficial effect in promoting the full realization of the potential of the fundamentally sound Bradley Infantry Fighting Vehicle.

With the publication of this report, ARI/Litton has researched, developed, tested and documented a significant number of potential solutions to complex problems associated with the fielding of a totally new weapon system. In the process of this effort, a major information base has been created that will permit investigation of more complex and untested conceptual approaches to equipment improvement, target surveillance and acquisition, advanced thermal training procedures, use of scale ranges and targets for sustainment gunnery training (both night and day/limited visibility), combat loading, and training device development and testing. These activities will constitute research to be conducted over the next two year period.

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